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CIVIL ENGINEERING.

On the Wear and Tear of Steam Boilers. By FREDERICK ARTHUR PAGET, Esq., C.E.

(Continued from page 102.)

From the Journal of the Society of Arts, No. 649.

4. *The Chemical and Physico-chemical Effects of the Feed-water.*

The wear and tear of a boiler which occurs in the form of corrosion, properly so called, may be divided into two principal kinds: (1.) Internal, and (2.) external. The progress of both is necessarily intensified by the mere effects of temperature; each, however, has its strongly marked, distinct character—not merely as to position, but also as to origin and results.

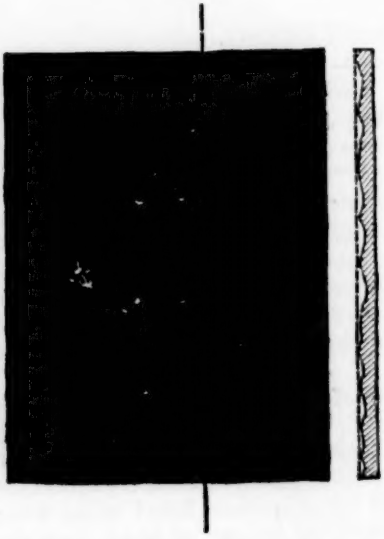
A steam boiler is in the position of a vessel into which large volumes of water are continually forced; while the heat applied, driving off all volatilizable matter, leaves behind a concentrated solution with a chemical character dependant on that of unvolatilizable matters in the feed-water. The specific gravity of the substances found in the water naturally causes them to sink towards the bottom, at which part the solution is generally more concentrated, however much it may be stirred up by the ebullition. Mr. J. R. Napier lately stated that a piece of zinc "about four feet long, by three inches broad, by three-sixteenths thick, placed in a marine boiler for three weeks" to a depth of 18 inches in the water, showed a corrosion which rapidly decreased "up to the highest part, which, in the steam, appeared to be little affected."* This accounts for the fact that all boilers, even those

* Institution of Engineers in Scotland, Session 1864–65.

internally fired, like locomotive boilers, have their plates most affected towards the bottom, and that internal corrosion always shows itself to a greater extent below the water line. The *bouilleur* of the form of boiler known as the French boiler, is also generally more affected than any other part. To resist this sort of slow action, it is clear that the more the bulk of metal the better, and it is for this reason that the bottom plates of most marine boilers are made thicker, while these same plates in locomotive boilers have to be often renewed. Any chemical or physico-chemical action of the kind is, of course, intensified by temperature, and this is one of the causes why externally fired boilers give way most a little in front of the furnace. But the plates above the water line also get more or less corroded, and not merely with the usual character of rusting, but in that peculiar form known as pitting, which generally shows itself much more strongly marked below the water line.

The presence of a concentrated solution of an acid or alkaline character, kept at a high temperature for years in contact with iron plates, would be sufficient to account for much corrosion. But the internal corrosion of steam boilers has many features of such a mysterious character, that no accredited explanation of its attendant phenomena has yet been put forward. In the first place, plates thus attacked show a number of irregular holes like a pock-marked human face, or like the small craters seen on the moon's surface. (See fig. 4.) The writer has also sometimes observed two or three little irregular excavations like this in a plate otherwise showing a large surface quite intact. Sometimes the plate is most pitted round a projecting bolt; at others, one plate will be perfectly sound, while that riveted to it will be almost eaten away, both having been the same time at work, and under, of course, apparently exactly similar conditions. With locomotive boilers this pitting has been ascribed to galvanic action between the brass tubes and the iron plates. But it is notoriously well known to locomotive superintendents, that boilers with iron tubes are often worse pitted than those which have run the same distance with brass tubes. Besides, all iron boilers, with or without brass, whether used for stationary, locomotive, or marine purposes, are subject to pitting.

Fig 4.



(The internal surface of a plate of an old wrought iron boiler, showing one-quarter of the full size the ordinary appearance of pitting.)

An explanation which seems to meet all the circumstances of the case is the following: Mr. Mallet, in a report addressed to the British Association some years ago, showed that wrought iron and steel (blister steel probably) "consist of two or more different chemical compounds, coherent and interlaced, of which one is electro-negative to the other." In fact, ordinary wrought iron, being also welded up from differently worked scrap, is far from being an electro-homogeneous body. In a boiler, the hot water, more or less saturated with chemical compounds, is the exciting liquid, and the electro-positive portions of the plates are thus quickly removed to a greater or less depth. This explanation meets most of the known circumstances with respect to pitting; it even, in a great measure, explains how plates above the level of the water, especially in marine boilers, get very rapidly corroded in portions, while another part of perhaps the same plate is scarcely affected. The concentrated water in a marine boiler is known to be generally acid. "Of all the salts contained in sea water," says Faraday,* "the chloride of magnesium is that which acts most powerfully" on the plates. He shows that a cubic foot of sea water contains 3·28 oz. of salt; and, at the same time, points to the danger of voltaic action in a boiler through the contact of copper and iron. In a smaller degree, the contact of cast with wrought iron, or between the different makes of wrought iron in the same plate, or between contiguous plates, acts in the same way. It is not improbable that some hydrochloric acid is present in the steam of marine boilers. "Mr. J. C. Forster† has tested some of the condensed steam from the safety valve casing, and from the cylinder-jacket of the Lancefield, and found both decidedly acid."‡ With an exciting liquid in the condensed steam, it is thus explicable how the plates of marine boilers often get corroded in a most capricious manner; while, at the same time, the current of steam would create a certain amount of friction on the oxide, clearing it away to act on the fresh surface.

The crucial test of this explanation of pitting would be the observation of the absence of the phenomenon from plates of an electro-homogeneous character. This homogeneity could only be expected from fused metal such as cast steel. Accordingly, while the writer was in Vienna a short time ago, he was assured by Mr. Haswell, the manager of the Staatsbahn Locomotive Works, that some locomotives made of cast steel plates in 1859, for the Austrian Staatsbahn, had been working ever since without showing signs of pitting, though, under similar conditions, iron plates had severely suffered in this way. Pitting may thus be fairly defined as a form of corrosion localized to particular spots by voltaic action. It is also probably aggravated through the motion of the plate by chemical action, and the expansions and con-

* Fifth Report of the Committee of the House of Commons concerning the Holyhead Roads, p. 194.

† Institution of Engineers in Scotland, 1864–65. Introductory address by Mr. J. R. Napier.

‡ When a solution of chloride of magnesium is evaporated nearly to dryness, the salt and the water are decomposed, magnesia and free hydrochloric acid being formed; or $MgCl + HO = MgO + HCl$.

tractions through alterations of temperature. All boilers are most pitted near the inlet for the feed-water, and with inside cylinder locomotive boilers there is generally more pitting at the smoke-box end —no doubt caused by the more or less racking action on these plates. A state of corrosion at particular spots would probably be kept up to a greater intensity by the incrustation being mechanically thrown off. With a quicker voltaic action, caused by any usual intensity of the exciting liquid, the sides of the cavities in the plates would be sharper and less rounded off, as in the case of the boiler fed with mineral water from ironstone workings, which exploded last year at Aberaman, South Wales. (See Fig. 5.)

The fact that pitting occurs in marine boilers when distilled water from surface condensers is used, does not affect this explanation. Water distilled in this way, from whatever cause, after repeated boiling, is stated to carry the salinometer even higher than sea water, thus proving it is not pure.* In the next, there is the absence of incrustation, which to some extent always protects the plates of boilers from the chemical action of its contents. In this way the mechanical buckling of the plates,—directly and indirectly causing the furrows we have spoken of—by continually clearing particular lines of surface from incrustation and oxide, reduces these particular spots, with respect to corrosion, to the condition of the plates of a boiler fed with water which deposits no incrustation. Corrosion will also act more rapidly at a furrow through mere increase and renewal of surface. To resist that form of internal corrosion specially known under the name of pitting, a maximum of electro-homogeneity is evidently required in all the component parts of the boiler.

Fig. 5.

(From a photograph of surface of corroded plate cut from one of the two boilers that exploded on Wednesday, February 17th, 1864, at Aberaman Iron Works, Aberdare. The corrosion was internal, and in some parts the plate was not more than one-eighth thick. Thirteen persons were killed, and many others seriously injured.)

While the action of internal corrosion, often very equally corrugating the plates over a large surface, as a rule scarcely, at any time only gradually, affects their mechanical strength, external corrosion,

* Institution of Mechanical Engineers, 1863. Discussion on Mr. James Jacks' paper "On the Effects of Surface Condensers on Steam Boilers."

being localized to particular spots, is of a much more dangerous character. The one is gradual and easily perceptible, while the other is rapid and insiduous in its progress. Apart from accidental circumstances affecting the brickwork on which a stationary boiler is erected, or the outside of the bottoms of marine boilers, it is clear that external corrosion can only occur through leakage. When leakage takes place through a crack in the plate caused by mechanical action, or at a hole burnt out by heat, the effects of leakage are only secondary results, due to a primary cause which of itself may cause the stoppage of the steam generator. But a leakage at a joint may in itself gradually cause the destruction of a boiler. Here we see another reason that the character of a boiler, not merely as to ultimate strength, but also as to wear and tear, intimately depends upon the form of its joints. It is often noticeable that very good lap-joints, even when tested under hydraulic pressure up to only 50 per cent. above the working load, sweat more or less. The tendency of the internal pressure to form a correct circle bears indirectly on these joints, causing them to open more or less, and to leak in spite of the caulking. Mr. Robert Galloway, C.E., who, as an engineer surveyor of long standing of the Board of Trade, has probably made more than three thousand careful inspections of marine boilers, states that he has often noticed a furrow or channel on the outside of a joint, running parallel to the outside overlap for some distance, and evidently caused by leakage. Along the water line, condensed water will act on the joints, while below it the concentrated contents of the boiler will come into chemical action. A leakage in a marine boiler often eats away a plate within a year. In some cases a jet of hot water from a leakage has a frictional action; in fact, even with such an incorrodible and hard substance as glass, an effect like this has been perceived, and a slight leakage continued during several days, sometimes produces a noticeable furrow on a glass gauge tube. With sulphurous fuel, a powerful chemical action will come into play on the plates. One volume of water takes up about thirty volumes of sulphurous acid gas; and these sulphurous fumes of the fuel coming into contact with the water from a leakage, will be more or less absorbed. An acid solution like this must quickly eat away the plate. It is certain that a leakage acts much quicker on a boiler fired with sulphurous fuel than on one fired with wood. M. G. Adolphe Hirn has observed a plate nearly seven-eighths thick, to be pierced, in the course of time, as with a drill, by means of a little jet which struck it after passing through a current of hot coal smoke.*

Legislative Enactments.

No stronger proof can be adduced of the empirical state of existing knowledge of the management of boilers than that afforded by a consideration of their average duration. While some marine boilers last only about three years, there are carefully worked land boilers which have lasted as long as thirty. Captain Tyler, R. E., estimates the average duration of a locomotive boiler at from five to twenty years.

* Bulletin de la Société Industrielle de Mulhouse, 1861, p. 558.

Perhaps the average duration of a marine boiler may be reckoned at from five to seven years; that of a locomotive boiler at from eight to nine years; that of a stationary boiler at from eighteen to twenty years; all being supposed to be fairly worked under ordinary conditions.

It is clear that, subjected as a steam boiler is to so many destructive influences, the precise effects of which can scarcely be yet very accurately known, the working tension should be only one-eighth of the ultimate bursting strength. But when boilers, as is too often the case in England, are bought by the weight; when cheaply paid labor is employed in their management; when inspection of the progress of the wear and tear necessarily happening even with good boilers and good attendance, is procrastinated for the sake of gain, there is then a suit of expense versus risk, in which parsimony too often gains the day. At any rate, a number of painful accidents in all parts of the world have, at different times, pointed to the fact that every man picked at hap-hazard cannot be safely trusted with steam power. In fact, there is probably no civilized country in which the legislature has not more or less interfered in the management of steam boilers. In the States of America, the frequency of boiler explosions has in some localities produced a more despotic interference than perhaps anywhere else. In the city of New York, boilers are under the supervision of the municipal police; they are tested periodically, and as a result many are condemned every year. By an enactment of Congress, applicable to all the States,* steam passenger vessels are subjected to government inspection. The 13th section of this Act shows a very acute perception of the real cause of a boiler explosion, "which," it states, "shall be taken as full *primâ facie* evidence" of negligence on the part of the owner, upon whom is thus put the onus of disproof. The law of Louisiana† is particularly severe, requiring the application of a hydraulic test threefold that of the working pressure. Of course, there is a great distinction between enacting a law and putting it into practical execution, and it is probable that laws like these could only be carried out by organized bodies of police, like those on the Continent. In France, in 1810, 1825, 1828, 1829, 1830, 1843, and lastly on the 25th of January, 1865, as many different regulations have been issued with respect to steam boilers of all kinds. Beginning by requiring that every boiler, even of wrought iron, should be submitted to a hydraulic test of five times the working pressure, this has been successively lowered down to a threefold pressure in 1843, and lastly to a twofold pressure by the Imperial decree of this year.‡ The previous law fixed the minimum thickness of the plates—a regulation which undoubtedly did much injury to boiler making in France. The old Prussian regulation of the 6th of May, 1838, also fixed the thick-

* Session of Congress, July 7, 1838.

† Baltimore American, 1835.

‡ Décret concernant la Fabrication et l'Etablissement des Machines à Vapeur. 25 Janvier, 1865.

nesses of the plates, but did not require any hydraulic test. By the *Regulativ** of the 31st of August, 1861, this was completely altered. The construction of the boiler was left entirely in the hands of the maker, but stationary boilers had to withstand a threefold, and locomotive boilers a twofold hydraulic pressure. In the same way as with the present French law, the test had to be repeated after any considerable repairs. On the 5th of March, 1863, a ministerial decree reduced the testing pressure for old locomotive boilers down to 1½ of the working pressure; and another *Circular Erlass*, published on the 1st of December, 1864, reduced the test for all kinds of boilers down to twice the working load. There is now no material difference between the French and the Prussian regulations respecting boilers; and it may be expected that those continental States, such as Russia, Switzerland, and Spain, which have more or less copied the old French law of 1843, will also adopt the present alterations. There is also some talk about altering the present Austrian law,† which determines the thickness of the plates, but only demands a double pressure test. The Belgian *réglement*‡ also requires double the working pressure for common boilers, but only 1½ for tubular boilers. According to Article 31, the test must be annually applied to locomotive, portable, and marine boilers, as also after all considerable repairs. There does not seem to be any general law in Italy, but in the special acts authorizing railway companies, similar requirements to the French regulations are laid down, and government commissioners see that they are carried out. Each of the smaller German States also has its law more or less like that of France and Prussia. Mecklenberg-Strelitz§ requires that common boilers be proved to three, and tubular boilers to twice the working pressure, to be renewed every fourth year, and every time that the boiler is repaired or altered; Saxony‖ that cylindrical boilers be tried to twice the working pressure, and tubular boilers to a pressure three atmospheres above it. Bavaria¶ now requires double the working power pressure for new, and one and a half for old boilers; while both Hanover and Brunswick each have a somewhat similar regulation.** The French law, and indeed most of the others, require two safety valves, and many are extremely minute in their directions with respect to glass gauges, steam gauges, and other fittings. In Great Britain there are no express legislative enactments with respect to boilers beyond those stated in two clauses of the Merchant Shipping Act,†† according to which (1) one safety valve in every boiler of a

* Dusseldorfer Zeitung. 24 ste September, 1861.

† Reichs-Gesetz-Blatt fuer das Kaiserthum Oesterreich, 1854, page 229.

‡ Ministère des Travaux Publics, Machines à Vapeur. Réglement. Donné à Læken le 21 Avril, 1864.

§ Grossherzoglich Mecklenburg-Strelitzer Offizieller Anzeiger, No. 11, 1863.

‖ Gesetzliche Verordnungen, die Anlegung von Dampkesseln betreffend. Dresden Meinhold und Sœhne, 1865.

¶ Regierungs-Blatt fuer das Kœnigreich Bayern, 22 Februar, 1865.

** Gesetz-Sammlung fuer das Kœnigreich Hannover, 1863.

†† Merchant Shipping Act, 27th June, 1854, Nos. 289 and 298.

vessel carrying passengers shall be placed beyond the control of the engine-driver; and (2) any overloading of this valve is made punishable by a fine of not more than £100, "in addition to any other liabilities" which may be incurred by such act. The boilers of all vessels carrying passengers before clearing out of port are subjected to a careful inspection by an engineer surveyor of the Board of Trade, who can require the boiler to be tested in the usual way to twice the working pressure; and if he thinks fit, he can, as the result of such an examination, place the option before the shipowner of either lowering the working pressure or renewing the boiler. Armed with such powers, the government surveyor is also responsible for any explosion which may directly occur through wear and tear. When an explosion takes place on a passenger railway, one of the Board of Trade inspectors of railways examines the fragments and reports upon the accident to the government board, who communicate it to the railway board. The reports are then printed, in order to be presented to Parliament, and this is the extent to which the British government can interfere in these cases. As with other railway accidents, however, the Board of Trade inspector is examined as a witness in any action for damages against the railway company. All other boilers in the United Kingdom are worked without any government or municipal interference whatsoever. Within late years, however, private companies (the first of which was organized by Mr. Fairbairn, of Manchester), have been formed for the prevention of boiler explosions. In return for a small annual fee, or for a small annual insurance premium, the boilers of any subscriber or insurer are periodically inspected, and, if required, tested by skilled engineers. There can be no doubt that these companies have already prevented a great amount of loss and disaster.

It may thus be said that there are three distinct plans for the general management of steam boilers: 1. There is the continental plan; 2. the free English and American mode; 3. what may be termed the Manchester system. The continental mode consists in a strict supervision, sometimes ruled by formulæ, of the original construction, and there its action may be said for the most part to end. It does not and cannot, without periodical inspections, take into account the effects of wear and tear. It may even be doubted whether the old French law, for instance, did not do more harm than good as regards construction. The official formula, according to which were calculated the thicknesses of the plates, founded as it was upon the assumptions that a cylindrical boiler formed an exact circle, and that a plate, however thick, conducted the same amount of heat to the water, was obviously incorrect. What may be termed the ordinary English and American plan throws the onus of proof of the negligence of the owner on those damaged by an explosion. This system is subject, besides other difficulties, to all the objections that exist against the trial of scientific questions by a jury not composed of experts and unaided by scientific witnesses. The continual occurrence of explosions in those cities and States of America in which boilers are used without any supervision by the authorities, and their undue occurrence in England with boilers that are not

subjected to systematic inspection, sufficiently prove that steam boilers cannot be worked at hap-hazard. On the other hand, the system of organized inspection by the English boiler companies, and the similar system, according to which the passenger vessels are inspected by government officers, have given universal satisfaction. A proper estimate of the value of the Manchester and Board of Trade system, compared with the continental and with the *laisser faire* plans, could only be well based on numerous statistics. Unfortunately, such do not appear to have been formed. It is stated,* however, that in an average of 277 boilers, there were two explosions in the French Department of the Haut-Rhin within ten years; and, from 1856 to 1861, or within five years, there were only two explosions in an average of 1371 boilers, under the care of the Manchester Association. About four explosions occur annually amongst the 6500 locomotives of the United Kingdom; three have already taken place this year. In an average of 600 passenger vessels inspected under the Steam Shipping Acts, only three explosions occurred since 1846–47 in Great Britain, viz: one at Lowestoff in the *Tonning;* another at Southampton in the *Parana;* and a third at Dublin. These last results speak very highly for the care and abilities of the engineer surveyors of the Marine Department; and the continental system is thus clearly inferior to that adopted by the Board of Trade. What is evidently wanted is, that the system of skilled periodical inspection should spread over the kingdom. To a certain extent this is taking place, but this progress is slow and needs some stimulus, while it is doubtful whether, in out-of-the-way districts, the mere expense of inspection is not a great bar. What seems to be needed is, that in the event of a fatal explosion, the coroner of the district should be enabled to write to the Home Office for scientific assistance in arriving at the originating cause. The Secretary of State might then call upon any competent engineer for a report on the matter, when he could be examined as a witness before the jury. The mere knowledge that any explosion would be strictly investigated by an expert, might, in many cases, be sufficient to counterbalance the too prevalent tendency to prefer risk to expense.

The Hydraulic Test.

Although, as we have seen, the application of a well known amount of hydraulic pressure is in such general use for the determination of the strength of a boiler, there are, nevertheless, few points in engineering about the real value of which there is so much dispute. Everybody seems to have a different opinion on the matter. Some say that the hydraulic test is the only means of determining the strength of a boiler; others that it is a very injurious and useless measure. As to its amount, some recommend one and a half, many twice, some thrice, and a few even four times the working pressure. While numerous engineers advise its application to old boilers, others have strong objections to its use in this way. Whether the force-pump be really the best apparatus for its application, is, with other questions, also placed in

* Bulletin de la Société Industrielle de Mulhouse, 1861, page 525.

doubt. The truth is, that while, on the one hand, like other tests, it may be abused and wrongly applied, on the other, its value may also be exaggerated.

The best practical proof of its necessity for new boilers is afforded by the fact that explosions have occurred the first time steam has been got up—such as that at the Atlas Works, Manchester, in 1858. Unless every plate be separately tested up to proof load, it is impossible to be certain whether one of them is not defective. This function is clearly much better performed by the hydraulic test. Then, as to its application to old boilers, much can be learned during internal examination, but it is not always possible to tell the remaining thickness of the plates by this means, nor their deterioration through the heat. It is often said that a successful resistance to the hydraulic test is no proof that the boiler might not have been burst by a few pounds more; and that it may so suffer as to perhaps afterwards burst with less pressure of steam. But this is no more true than it is true of a girder, for instance, which has withstood, without permanent deflection, its proof load. In every case it is necessary that its effects on the boiler should be exactly ascertained. In fact, the real test consists in this examination, and the proof pressure is only a means to this end. The boiler should, if possible, be subjected to a careful internal and external examination. With locomotives this can only be accomplished by taking out the tubes; with ordinary land boilers it can only be done by removing the brickwork. In fact, it may be said that a steam boiler is never absolutely safe which cannot be easily examined—more especially from the inside. But by gauging the flue tubes, the combustion chambers, the flat surfaces, and even the barrels, it may be ascertained very nearly whether the limits of elasticity of the material have been exceeded—whether therefore the pressure has additionally injured a boiler which was near rupture already. It is often very plausibly observed that there is great danger in testing a boiler, which cannot be examined internally to double, or even to only one and a half the working pressure. It is said that the test may strain the boiler without its showing any outward indication. It is certainly just possible that such a case might happen. A locomotive boiler, which had been tested with 196 lbs. pressure, the water being at 162° Fahr., in September, 1860, but had not been examined internally, burst on the 1st of April, 1861,* under only 120 lbs. of steam. The boiler gave way at the smoke box ring of the barrel, and, as usual, from a furrow or crack running close to and parallel with the inside overlap of the longitudinal joint. It is difficult to believe that if this ring, as well as the others, had been gauged after stripping the lagging from the outside, as is done by the engineers of the Manchester Boiler Association, it would not have shown a permanent increase of diameter or some bulging under the extra pressure. If, in addition to a neglect of careful measurements before and after the application of the pressure, this test is carried very high, then the whole operation may undoubtedly be a cause of that which it is intended to prevent. According to

* Board of Trade Report. 1861. Part 4.

the Prussian law, every new locomotive boiler had to be re-tested to double the working pressure after running 8000 Prussian miles, and afterwards for each 5400 miles. These measures, while they did not entirely prevent explosions, greatly injured the boilers, by straining the stay bolts, and by the resulting excessive caulking required to make the joints tight. On the other hand, the absolute security afforded by drawing the tubes can, under the present mode of construction, be only obtained at the expense of perhaps 300 tubes, costing from 25*s.* to 27*s.* each, besides some injury to the tube plates.

Whatever may be said against the hydraulic test, the best argument in its favor is its very general adoption. New government boilers in the United States must be tried to a pressure two-thirds greater than the working pressure; the same measure being carried out with the 3000 boilers in the city of New York. Mr. Anderson, C.E., of Woolwich,* directs his subordinates to use a test of at least double the working pressure for the boilers in the royal gun factories. Mr. Muntz, of Birmingham, has publicly stated that he has for years adopted an annual hydraulic test, "considering it a duty he owes to his workmen." The Eastern Counties, the South Eastern, the Lancashire and Yorkshire, the Caledonian, the North British, the Edinburgh and Glasgow, and the London and South Western Railway companies employ the hydraulic test for both new and old boilers, using generally double the working pressure. The London and North Western are stated to have used it for only new boilers—at any rate until recently. The Great Northern and the Great Western Railway companies do not use it, and it is accordingly on these lines that the greater number of explosions take place. Practical experience thus proves that, though there is just a chance of the test failing to detect a weak boiler when it cannot be examined internally, the danger is greater in not using the hydraulic test at all. Mr. Beattie, of the London and South Western, strips the lagging every two years, and applies a pressure of 190 lbs., the working pressure being 125 lbs. Mr. Fletcher, of the Manchester Boiler Association, employs double the intended working pressure for new, and from $1\frac{1}{2}$ to $1\frac{3}{4}$ the working pressure with old boilers. The most commonly used test is thus double the working pressure for old boilers, with a diminution according to circumstances as they get old.

An objectionable plan in measuring the pressure applied, and, for several reasons, one likely to lead into error, is estimating it from the load on the safety valve lever. A metallic gauge should be used, and very neat pocket instruments of the kind are sold in Paris. In frosty weather the rivet heads are liable to be snapped if the metal be not somewhat warmed by using hot water. The hydraulic ram kind of action on the sides is also much less likely to occur if a rather narrow force pipe be used for the pump.

There can be no doubt that it would be a valuable thing to be able to employ some means of measuring the permanent and temporary

* "Instructions to be Observed in the Management of Steam Boilers in the Royal Gun Factories."

extension of volume, if any, produced by the hydraulic test. It is probable that a boiler, as it gets old, and takes a permanent set under the pressure, also increases in volume; so that it doubtless holds a few gallons more than it did when new. An ingenious plan for measuring the increase of volume is recommended in the Bavarian regulation. After the boiler is filled, the amount of water forced in is measured by pumping it from a vessel marked with divisions. When the pressure is removed, the boiler contracts more or less, forcing out at least a portion of the water; the amount remaining is supposed to give the dilatation of volume of the boiler. The difficulty in the use of this plan would probably consist in the presence of air in the water itself, and any which might chance to remain in the boiler. That in the water might be greatly diminished, or at any rate brought down to a constant amount by boiling; but there would be no precise security against any air in the boiler, and as the weight of the air absorbed by water (according to a well known law) is in proportion to the pressure, it would be taken up by the water, thus falsifying the indications when the pressure was removed. On the other hand, a high temperature of the water would form an impediment to this absorption. The experiment is certainly worth trying. It might be very valuable with tubular boilers inaccessible from the inside, as any permanent set or deflection ought to be indicated by little or no water being compressed out by the contraction of the boiler on the removal of the pressure. As long ago as 1844, M. Jobard, of Brussels, in order to obviate the supposed injurious effects of the hydraulic blow of the water on the plates, proposed to fill the boiler with water, first loading the safety valves, and to then dilate the water, and consequently the boiler, by means of heat applied to the outside.* More recently, Dr. Joule, of Manchester, has used the same plan himself, proposing it for general adoption.† In addition to the loaded safety valve, he used a metallic pressure gauge "to be constantly observed, and if the pressure arising from the expansion of the water goes on increasing continuously without sudden decrease or stoppage until the testing pressure is obtained, it may be infered that the boiler has sustained it without having suffered strain." Another plan, also founded upon the same principle of the irregularities of extension of metals when the limit of elasticity is exceeded, has lately been proposed.‡ This consists in bringing an ordinary steam engine indicator in communication with the pump plunger as if it were a steam engine piston rod. The ordinates of the pencil diagram would thus give the pressure in the boiler, while the respective abscissæ would give the quantity of water pumped in at each stroke. As long as the limit of elasticity was not exceeded there would be a horizontal line, while a curved line would appear as soon as the sides began to take a permanent deflection. There seems to be a sort of contradiction in depending for results like these upon such irregular appearances as

* "Technologists," 1844, page 135.

† "On a Method of Testing the Strength of Boilers." Journal of the Manchester Philosophical Society, 1862, page 97.

‡ Polytechnisches Centralblatt, page 1337, 13th October, 1864.

the extension beyond the elastic limit. But all these proposals are undoubtedly worth trial in practice. Dr. Joule's plan has the merit of affecting the plates by both heat and pressure, thus bringing them under every day conditions.

(To be continued.)

Temperatures and Pressures of High Pressure Steam. By R. A. Peacock, C.E., Jersey.

From the London Artizan, June, 1865.

An examination of the following table—which has never been published before, and, with the exception of Dr. Fairbairn's experiments, is quite new—will satisfy the reader that from 25 lbs. per square inch up to 411·6 lbs. per square inch, the temperature increases as the $4\frac{1}{2}$ root of the pressure. The greatest variation from M. Regnaults experiments is with his temperature of 300° Fahr.; such variation, however, is less than $\frac{1}{4}$ per cent., viz: ·232, or 1 in 431. It will be further observed that even with regard to that small variation, the result ought to be considered as modified by the very close approximation of the calculation to Dr. Fairbairn's experiments with a temperature only a little less, viz: 292·53° Fahr., for which the calculation gives a difference of only ·017 per cent., or 1 in 5882. With M. Regnault's temperature of 410° Fahr., the calculation is all but identical, the difference being only ·002 per cent., or 1 in 50,000, while with his last temperature, viz: 447° Fahr., the difference between experiment and calculation is still unimportant, being no more than ·159 per cent., or 1 in 629. And it may be further observed, that the formula, *Temperature increases as* $4\frac{1}{2}$ *root of pressure*, is, so to speak, still more moderate than M. Regnault's own formula; because it will be seen that the former requires 447·71° to give the pressure of 411·6 lbs., whereas M. Regnault's formula gets that pressure with 447° Fahr. only. That is to say, if both formulæ were to be applied (hypothetically) to calculate very high temperatures of, say, 2000° or 3000° Fahr., M. Regnault's formula would give greater pressures than the other. Probably the means do not exist for ascertaining how far either formula differs from fact at those high temperatures.

Yet, although exact knowledge does not exist, we are fortunately not without some indications of the force of steam pressure at very high temperatures. The Rev. John Michell wrote a very valuable paper, in which he contended that earthquakes were caused by steam,* which paper does not appear to have gained as much consideration as it probably deserves. He says that in casting two brass cannon "the heat of the metal of the first gun drove so much damp into the mould of the second, which was near it, that as soon as the metal was let into it, it blew up with the greatest violence, tearing up the ground some feet deep, breaking down the furnace, untiling the house, killing many spectators on the spot with the streams of melted metal, and

* Phil. Trans. R.S., 1760, vol. xi., p. 447, &c.

Pressures per Square Inch.	Regnault's Experiments.	Dr. Fairbairn's Experiments.	As $4\frac{1}{2}$ Roots of Pressures.	Differences.	Differences per cent.
lbs.	Temp. F. deg.	Temp. F. deg.	Temp. F. deg.	deg.	deg.
24·998	240		240·244	— ·244	— ·102
26·5		242·90	243·375	— ·475	— ·195
27·3518	245		245·093	— ·093	— ·038
27·4		244·82	245·188	— ·368	— ·150
27·6		245·22	245·585	— ·365	— ·149
29·8753	250		249·946	+ ·054	+ ·022
32·5899	255		254·824	+ ·176	+ ·069
33·1		255·50	255·705	— ·205	— ·080
35·5005	260		259·715	+ ·285	+ ·110
37·8		263·14	263·362	— ·222	— ·084
38·6169	265		264·617	+ ·383	+ ·145
40·3		267·21	267·137	+ ·073	+ ·027
41·7		269·20	269·17	+ ·03	+ ·011
41·9587	270		269·543	+ ·457	+ ·170
45·5259	275		274·474	+ ·526	+ ·192
45·7		274.76	274·71	+ ·05	+ ·018
49·3332	280		279·417	+ ·583	+ ·209
49·4		279·42	279·50	— ·08	— ·029
51·7		282·58	282·34	+ ·24	+ ·085
53·3953	285		284·374	+ ·626	+ ·220
55·9		287·25	287·29	— ·04	— ·014
56·7		288·25	288·20	+ ·05	+ ·017
57·722	290		289·34	+ ·66	+ ·228
60·6		292·53	292·48	+ ·05	+ ·017 = $\frac{1}{5882}$
62·328	295		294·319	+ ·681	+ ·231
67·2231	300		299·306	+ ·694	+ ·232 = $\frac{1}{431}$
72·422	305		304·302	+ ·698	+ ·229
77·9345	310		309·303	+ ·697	+ ·225
83·7802	315		314·315	+ ·685	+ ·218
89·9689	320		319·332	+ ·668	+ ·209
96·5104	325		324·352	+ ·648	+ ·200
103·4292	330		329·381	+ ·619	+ ·188
110·7302	335		334·412	+ ·588	+ ·176
118·433	340		339·446	+ ·554	+ ·163
126·5523	345		344·486	+ ·514	+ ·149
135·1028	350		349·527	+ ·473	+ ·135
144·0992	355		354·565	+ ·435	+ ·123
153·5562	360		359·614	+ ·386	+ ·107
163·4934	365		364·660	+ ·340	+ ·093 = $\frac{1}{1075}$
173·9206	370		369·705	+ ·295	+ ·079
184·8574	375		374·750	+ ·250	+ ·067
196·3234	380		379·795	+ ·205	+ ·054
208·3284	385		384·838	+ ·162	+ ·042
220·8871	390		389·876	+ ·124	+ ·032
234·024	395		394·918	+ ·082	+ ·021
247 7538	400		399·949	+ ·051	+ ·013
262·0912	405		404·980	+ ·020	+ ·005
277·0509	410		410·007	— ·007	— ·002 = $\frac{1}{50000}$
292·6525	415		415·029	— ·029	— ·007
308·9156	420		420·047	— ·047	— ·011
325·85	425		425 058	— ·058	— ·014
343·4753	430		430·063	— ·063	— ·015
350·7224	432		432·063	— ·063	— ·015
411·6*	447†		447·71	— ·71	— ·159 = $\frac{1}{630}$

* = 28 atmospheres, and † = 230·56 centigrade. See Rev. R. V. Dixon's "Treatise on Heat," p. 183.

scalding others in the most miserable manner." These great effects were evidently produced by the steam of a few ounces of water only, for it is called merely "damp," and it must, therefore, have been very powerful steam. Now, according to the late Professor Daniell, F.R.S., brass melts at 1869° F., but the heat of the steam could not have been as much as that, because, amongst other reasons, a portion of the heat must have been taken up by raising the temperature of the "damp," and the "mould," and the neighboring sand. If the temperature of steam could have been 1869° F., the hypothetical pressure would have been by the formula, 114 tons per square inch; but the real force consequent on the reduced temperature most likely was considerably below 100 tons. What is intended to be inferred is, that the pressure of steam continues to increase at all events as high as up to water converted into steam by an initial heat of 1869° F. The law of increase may either be according to either of the formulæ, or to some of the other well known formulæ, or to some other unknown law, but at all events the force *had* continued to increase.

The columns headed "Pressures per square inch," so far as they relate to M. Regnault's experiments, are reduced from Table I, pp. 259–260, of the Rev. R. V. Dixon's "Treatise on Heat,"* where he gives the pressure or force in inches of mercury. He was elaborately accurate in reducing M. Regnault's temperatures and pressures to English denominations, having calculated the values of the constants from Vlacq's tables, in which the logarithms are given to ten places of decimals, (p. 252.)

Further particulars of this formula appeared in the *Artizan* of January and February, 1864.

The present writer exhibited before the Mathematical and Physical Section of the British Association at Bath (but did not read) a MS. containing about sixty evidences of the presence of water in some of its forms, in every species of natural disturbance of the earth's crust. Additional evidences have since been collected, and the whole number now amounts to about seventy; and a summary of these evidences gives the following results:

Humboldt, who, perhaps, personally inspected more volcanos than any other man who ever lived, and Sir Humphrey Davy, both condemn the alkaloid theory as co-operative only; and

1. We have Humboldt, Davy, Lyell, Von Buch, Dana, Sir William Hamilton, Dr. Scherzer, and three anonymous writers, testifying to the ejection of abundance of steam from volcanos generally, and some of them from Vesuvius in particular.

2. Steam is ejected from earthquake fissures.

3. It is *said* that steam is exclusively the moving force in geysers, and *proved* that it issues from them in great force and abundance.

4. Large rocks are ejected by steam.

5. Submarine volcanos necessarily produce steam, and one of them has been active for 2000 years. Earthquakes often accompany. Steam was very active when Graham Island rose from the Mediterranean.

* Hodges and Smith, Dublin, 1849.

6. In 1822, at Galangoon, in Java, the waters of the river Kunir, which flowed from the flanks of a volcano, became for a time hot and turbid. About two months after there was a loud explosion, and immense columns of hot water, boiling mud, burning brimstone, ashes, and lapilli were projected like a water-spout, with prodigious violence, and to a great distance. The first eruption lasted nearly five hours, and on the following days the rain fell in torrents, and the rivers, densely charged with mud, deluged the country far and wide. At the end of four days, a second eruption occurred more violent than the first, in which hot water and mud were again vomited, and great blocks of basalt were thrown to a distance of seven miles. There was at the same time a violent earthquake, and 2000 people were killed.

7. Hot or boiling water and rocks are ejected from volcanos, and sometimes accompanied by earthquakes. A large lake has its level lowered during a volcano and earthquake, and two small rivers disappear and break out again as hot springs.

8. Water, often hot, is ejected from earthquake fissures, and from risings and sinkings of strata.

9. Earthquakes are fed by water.

10. Deposits of water, ice, or snow are ready to descend into volcanos by gravitation.

11. Active volcanos are fed by water, and absorb all the rain which falls upon them.

12. Volcanos in action, earthquakes, hot water, and increased heat of hot springs, are sometimes all connected together.

13. The lava of five volcanos emits copious volumes of steam or gas.

14. In extensive reading on the subject, the writer has found no reason to believe, nor any allegation, that steam or its components is ever absent.

15. "A deplorable accident has lately happened at Etna by an explosion caused by the contact of burning lava with some cistern or watercourse, by the effects of which a number of sappers are reported to have lost their lives, but the particulars are not known."* Thus steam and hot water have literally a great deal to do with volcanos and earthquakes, for steam cannot be idle.

The ancient Greeks used to personify everything. Would they not, if they had known all these things, have been likely to represent Etna pointing to the explosion of the cistern as the principle of her own explosions? And ought not the same point to be a grave question now?

Sir Henry de la Beche and Mr. L. L. Dillwyn made experiments† by which they found that Cornish granites and elvans melted with a heat about equal to that required for melting malleable iron, which is the greatest heat that can be obtained in a smith's forge. But even

* Mr. J. J. Jeans, British Vice-Consul at Catania, Feb. 4, 1865. See *Illustrated London News*, Feb. 25, 1865.

† Sir H. de la Beche's "Cornwall," p. 191, foot note.

with this great heat black non-lithia micas remained unfused. We may, therefore, safely assume, for these and other reasons, that the heat of melted lava is not less than 3000° F. But since we have seen that the force of steam has increased according to some unknown ratio up to an initial temperature of 1869°, it would be contrary to all precedent, and therefore rash to assume that there is not also a further increase with 3000°.

Supposing, for the sake of argument, and by the way of illustration, (for the moment only,) that the temperature continues to increase as the $4\frac{1}{2}$ root of the pressure until the net thermometrical temperature of the steam has become 2200° F., which Professor Daniell found is the heat of melted gold. Then the (hypothetical) pressure would be 237,494 tons per square inch, which, by calculation, would suffice to propel a certain large mass of granite from a supposed focus three miles below sea-level up to one mile above sea-level—in all four miles of vertical height, inclusive of the resistance of the air, which is very great. It would follow, then, that it is *possible* that there *may be* such a thing as steam powerful enough to produce the greatest effects of earthquakes and volcanos, for 2200° is by no means the maximum temperature attainable.

For the Journal of the Franklin Institute.

Cut-offs.

The controversy between the Navy Department and the builders of the *Algonquin*, enlivened by the trenchant letters of the constructor of her engines, has forced on public attention the subject of expansion by cut-offs. The sympathies of many practical men are with the builders. They endorse their confidence in the superior qualities of the engines, and their defiance of official opponents. Still, the principles of physics, on which the result depends, are inexorable and insensible to moral suasion or censure. There are those who think the mighty agent, upon which progress depends more than on anything else, has passed through every form and phase of trial, and that its value as a motor is exhausted in modern engines; others, with more reason, believe that, so far from our knowledge of it being complete, much of importance is yet to be acquired. Unacquainted with the parties contending and their experiments, without a shadow of interest in cut-offs, or the slightest prejudice in favor of or against them, I think it has happened to them as to other devices, to which credence has been given without due examination, and opinions taken up on trust. At the risk of having the remark applied to myself, I think they are imperfectly understood. The following thoughts are thrown out with the sole view of aiding in the discovery of the truth.

To economize steam by expansion has been a desideratum for well nigh a century, and nothing conclusive has been attained. Conflicting opinions are still rife, and the government has charged a commission of experts to solve the problem by a fresh set of experiments. I have

no faith in doubtful or hazy explanations of mechanical matters, nor is there any reason why any one should. Whatever is uncertain vanishes when thoroughly looked into, and every man of ordinary talent and persistance can do that. Such is the case with steam.

Although the leading element in the civilization of our orb, and one in all probability never to be superseded, the properties of aqueous vapor are as palpable and plastic as those of other bodies. As complete control of it may be had as of them. It is weighed in the same scales and its quantities ascertained by the same vessels of capacity as liquids and solids. A pound of it is a pound of water vaporized. The mode of using the measures is somewhat different than with liquids, but not less rigid and correct. One holding a cubic foot of water has to be emptied and filled afresh until the required number is made up, whereas with steam several feet are commonly contained in the space of one, the number being indicated by the pressure. Hence *pressure* and *quantity* are *complements and explicatives of each other.* As volume increases, pressure diminishes, and *vice versa*, the quantity remaining the same. The smaller volume may contain the larger: Five cubic feet whose pressure is 40 lbs. on the inch, contains ten feet of 20 lbs., or 20 feet of 10 lbs., all three being equivalents in cost, quantity, and power. The knowledge of this is essential to a correct appreciation of cut-offs, since as much, or even more, steam may be let into a part of a cylinder than would suffice for the whole.

It will be understood that I speak here of *natural steam*, not of that doctored by heat and more or less decomposed after actually or virtually leaving the boiler,—steam, of which every cubic foot contains, in round numbers, a cubic inch of water, and in the using of which nothing is left in doubt—nothing to mystify or perplex,—steam, whose power is increased by increasing its quantity, just as more heat is obtained by consuming more fuel, more light by turning on more gas, more wind power by enlarging sails to catch more of it, as the force of a gun is increased by adding powder to the charge, and that of men and animals by increasing their numbers. To double the power of steam, the fluid must be doubled. Such we take to be the only reliable theory of forces, whether the motive agent be an elastic fluid, a liquid, a solid, or a living body. Yet vast amounts of time, talent, and money, have been and are still being spent to prove steam an exception. Superheating it may, in certain cases, be found useful to prevent premature condensation, but that its value as a prime mover is thereby increased has yet to be established. It adds nothing to the substance of the fluid. Another query is, whether any alleged gain does not cost, all things considered, as much or more than it is worth.

If a sluice-gate be arranged to deliver more water on one part than on another of an overshot wheel, no more power could be got from it than from the uniform discharge of the same quantity upon it. The power would be in the weight of the liquid, and that would be the same in both cases. So with steam: it is the quantity let into the cylinder that determines the power, not the mode of letting it in. This is, however, questioned. Advocates of cut-offs insist that when the whole force

or charge is opened on the piston in the first part of the stroke and left to expand and follow it to the end, a better effect is obtained than from an equal (or even greater) charge let in regularly from the beginning to the end, or near the end of the stroke.

It has been thus accounted for: "By the momentum given to the matter which the engine is moving—it may be the fly-wheel, or the steamboat itself, or the train of cars, all of which, when once set in motion, will not suddenly stop, even though all power were suddenly suspended from driving them, and which therefore will continue to go on under the diminished pressure of the expanded steam. Thus you see that when the steam is cut off from the cylinder, that which is in it continues to push on the piston with diminished force, but still with some force; and as the piston cannot stop, it absorbs, and through the wheels which it drives gives out again to useful effect whatever pressure is thus spent upon it, just as your watch will run all day, although the spring which drives it grows weaker and weaker as it is relaxed.

"The gain which can be obtained from the use of expansion is measured by the extent to which you carry it; or, in other words, how short you cut off the steam in the cylinder.

"Ten expansions will do three times and a third as much work as no expansion, using the same amount of fire and steam."

Progressive movements dependent on varying momenta abound in every department of nature. Animals that go forward by springs or leaps are examples. The path of some birds through the air in a succession of ascents and descents—a series of undulations or curves—rising by the action of their wings and descending without it. The principle of thus applying force is therefore a sound one, and the question is its adaptation to artificial machinery and propulsion. We find it confined by the Great Engineer to organisms specially fitted for alternations of leaps and stops, and whose functions are incompatible with uniform speed. Neither the locomotive organs of natural machines, nor the conditions under which they act, are applicable to ours, nor ours to them. There is not a rotary propeller in nature, while we have in the *wheel* the most equable and perfect instrument of progression. Its supreme excellence is its complete adaptation for receiving and transmitting continuous motion without jarring the masses it moves, and consequently without a varying momentum. With cut-offs there is of necessity an inequality of pressure on the pistons, and therefore an inequality of motion in bodies impelled by them,—an effect fatal to stability and durability.

If the second proposition in the quotation is to be received, the laws of force and resistance would seem to be at fault.

The next dictum is specific and not to be misunderstood. Could it be proved, a chief niche in the world's Walhalla would be due to its author. That by the same quantity of steam more than three times the work can be performed with a cut-off than without one is incredible, and if true a miracle almost as great as making three gallons of water out of one. If the resistance were greatest at the beginning of the stroke, and fell down to zero at the end of it, there might be

cause for some gain, but, so far from that, it may be considered uniform in bodies moved by steam, whether ploughs, ships, cars, or manufacturing mechanisms. Whatever may be said to the contrary, we must continue to believe, till controverted by facts, that there can be no saving of steam power by substituting a succession of impulses for continuous pressure, except in cases where the resistance rises and falls with the piston's movements. Whether there are such cases we know not, but it is certain that sudden changes of force and velocity are not the things for steam machinery, no more than are springs and leaps (sensible or insensible) for bodies moved by it.

The popular idea is illusive. It is the impression of many that when the cut-off acts at half-stroke, half is saved; at one-third, two thirds; and at one-fourth, three-fourths. They forget that pressure indicates quantity. Engines with cut-offs of necessity use steam of greater tension than others, and the less the charge the greater the tension. The only difference is that one class uses small volumes of high pressure, and the other large volumes of lower pressure, the requisite quantity being the same in both. An engine is worked with steam of 100 lbs. on the inch, and cuts off at half-stroke. The mean pressure of the latter half is, therefore, 75 lbs, and that of the whole stroke 87 lbs. on the inch. Observe that twice the force is expended on the first half than suffices for the latter half, and (the resistance being the same) twice the amount required. Where then is the difference in the amount consumed between charging the cylinder with 87 lbs. steam, and with it varying from 100 to 50 lbs. In every case as much of the fluid *must* be admitted as will push the piston to the end of the stroke, whether sooner or later cut off. Another engine has a cylinder of the capacity of twelve cubic feet; and requires steam of not less than 12 lbs. per inch pressure. This does the work without a cut-off. Suppose it be determined to apply one and cut off at half-stroke, would not the tension have to be raised to 24 lbs. on the inch, if cut off at one-third to 36 lbs., and if at one-fourth to 48 lbs? In fine, does it not follow that *theoretically* there is no more to be gained by cutting off at a quarter than at half-stroke, and no more by that (unless in special cases alluded to) than with no cut-off at all. To determine how far practice conforms to theory there is a conclusive experiment—apply the same *quantity* of steam used with a cut-off to the same cylinder without one.

E.

On the Erith Explosion, and the Repair of the Thames Embankment.

By Lewis Moore.

Read before the Society of Engineers, Nov. 7th, 1864.

From the London Mechanics' Magazine, November, 1864.

On the south side of the river Thames, between Woolwich and Erith, are several magazines used for the storage of gunpowder, belonging, some to Government, and some to private firms engaged in the manufacture of gunpowder. These are situated within a few yards of the

bank of the river, for the convenience of loading and unloading by water, that being the most convenient and economical, as well as the safest method of transit. These magazines occur at intervals of half a mile or thereabouts. In the river, moored close to the north shore, were, until recently, three or four large hulks, used also for the government storage of powder. Now, however, there exists but one, that being moored between North Woolwich and Barking Creek; the others, which formed part of the Government store at Purfleet, have been removed. On the north bank of the river there appears to be only one magazine in this neighborhood beside the royal magazine at Purfleet. Full details of the arrangements of these magazines have so recently appeared in the public journals that it is unnecessary here further to notice them, save as to their relative positions with regard to the subject of this paper; and this will be clearly seen on reference to the map of the general locality (No. 1).

The scene of the recent explosion was on the south side of the river, in the Erith and Plumstead Marshes, and the magazines which were destroyed were the property of Messrs. John Hall and Sons, of the Faversham Mills, and of the Elterwater and Lowood Gunpowder Companies. The relative positions of these magazines to each other, and to the bank of the river and the adjoining cottages, &c., will be clearly seen on reference to diagram No. 2, which is from actual survey. The magazine of Messrs. Hall and Co. was a substantial brick building, 50 feet square and two stories high, and was situated at the back of the river wall or embankment, on the marsh, at a level of 7 feet or 8 feet below Trinity high-water mark. From this magazine a jetty projected into the river to low-water level. This jetty was used for the shipment of gunpowder, and crossed the river wall on the level of the footpath. In this magazine, and in two barges, which at the time of the explosion were moored, one at the end and one at the side of the jetty, there were about forty-two tons of gunpowder. The magazine of the Elterwater Company was situated 64 yards to the eastward of Messrs. Hall's stores. This building was a similar construction, and measured 50 feet by 28 feet, and contained about 4½ tons of powder. The next nearest magazines were those of Messrs. Curtis and Harvey, which are about 700 yards distant to the westward. The buildings adjacent were the manager's house and two or three cottages, inhabited by men employed at the magazine.

The river wall at this point consisted of an ordinary puddled clay embankment (the top of which was about 4 feet 6 inches above Trinity high water), battered about two to one, and faced on the river side with stones, to protect it from the wash of the sea; along the top was a foot-way about 4 feet or 5 feet wide. At the foot of the wall, on the land side, was the marsh that it reclaimed, and on the river side a shelving mud bank, falling at about the rate of one in six or seven to low water. The section will be clearly seen in diagram No. 3.

Trinity high water is 12 feet 6 inches above ordnance datum, but the spring tides have been known to rise to a level of 16 feet—14 feet being the height to which they frequently rise. At the time of the

explosion which took place at twenty minutes before seven o'clock on the morning of Saturday, the first of October last, the tide was ebbing, and was within an hour and a half of low-water—a most fortunate circumstance; for, had the accident occurred one hour later, it would have been impossible to reinstate the wall, and the marshes, as well as some of the surrounding country, must inevitably have been inundated, as it was impracticable (as afterwards proved) to have contended with the flowing tide in the limited time available. Of the immediate cause of the accident it will be here unnecessary to speak, as that will probably never be known; but with regard to the results there is more tangible matter to deal with. From the evidence afforded by the displacement of earth at various points, there is every reason to believe that there were three distinct explosions, occurring probably in the following order: 1. The barge lying alongside the jetty and near the bank; 2. Messrs. Hall's magazine; and 3. The Lowood Company's magazines. The barge at the end of the jetty is presumed to have been empty, as no disturbance appears in the soil beneath where she lay, whereas in the other cases the earth was blown out to a considerable depth, presenting the appearance of a smouldering crater, with fissures in all directions. The reasons which lead to the supposition that the explosions occurred in the order above stated are that portions of the river wall were found in the hole or pit caused by the barge exploding, and this could only have been the case by the magazine exploding after the barge, and forcing the wall back towards the river, thrusting portions of it into the pit already formed by the barge. Had the magazine exploded first and thus ignited the barge, the ground beneath her would have been clear of fragments, as the wall would probably have been blown inland by the last explosion. The magazine last referred to would communicate with that of the Lowood Company, which, in its turn, was demolished. The concussion caused was felt from 60 to 100 miles off; this was the result of the explosion of 46½ tons of gunpowder or 1040 barrels, each containing 100 lbs. The effects to property, both immediate and remote, are universally known; as regards the river wall, a breach was made of 130 feet in length, the earth being cleared away 8 feet or 10 feet below the level of the marsh, exposing the whole of the country to the rising tide for about five hours every high water, or twice in twenty-five hours. The extent of land positively imperilled would be about 4000 acres; and should it have passed Woolwich and Greenwich by the large sewer it might have done immense damage, the whole of the southern and eastern side of London being more or less below the level of high water. The full estimate of the impending calamity can only be realized by those acquainted with the levels of the localities referred to, and the character of the banks of the Thames. Diagram No. 4 shows a section of the river wall after the explosion, the dotted line shows a contour of the temporary dam. In an able article in the *Builder*, upon the subject of the catastrophe, the fortuitous conjunction of circumstances is thus described: "Every circumstance of time and tide, availability of competent direction, presence of men at the works of the main drainage,

vicinity of a great and disciplined military force with tools and appliances, and even the soil at the spot, happened to be favorable; and a more serious disaster than has occurred within recollection, by a breach in an embankment of the Thames, was, by the greatest exertions, stayed off and at length averted. The instance may be instructively compared with the experience of previous accidents, as related in various books, where the loss to landowners, and the injury to the navigation of the Thames, through the year's duration of breaches, and by the repeated failures of attempts to close them, is graphically related."

The author of the paper, residing in the locality, was enabled to be on the spot within half an hour of the explosion, and seeing that the sufferers were properly cared for, he proceeded to the immediate repair of the wall, although, at the time, the reinstatement of the wall before the return of the tide appeared hopeless, such was the magnitude of the gap. The first step was to set to work the men who were fortunately present, in number about forty—these were set to puddle the rents and deep fissures in the hole caused by the exploded barge, and which were below low-water level, but were temporarily protected by the fragments upheaved around the edge of the hole; had not this been done before the water came into the hole, it could never have been got at again, and the whole superstructure, however solid, must have been undermined and washed away. It may be readily inferred that the bases of operations were of the worst possible description, being lumps of earth and clay separated by large fissures several feet in length, and extending under the intended dam. The next thing was to send for assistance from the nearest point; fortunately this was obtainable at the Crossness works, about a mile off, and at the garrison at Woolwich, about four miles distant from the spot. At about ten minutes before nine o'clock, the call was promptly responded to by the arrival from the Crossness works of about 350 navvies, with their picks, barrows, &c., who came none too soon to complete the puddling of this treacherous foundation before it was covered by the tide. Between ten and eleven o'clock 1500 military arrived, fully equipped with some appropriate implements, and they devoted themselves entirely to the backing up with immense quantities of earth, the work which the navvies were puddling in front, thus making it sufficiently substantial—consistent with speed and means at hand to contend with the now rapidly rising tide. In this, as is well known, by a manful struggle, they only just succeeded—racing, as it were, inch by inch with the rising waters.

Having given a general outline of the subject of the paper, it is now necessary to consider in detail the means employed and the measures taken to prevent the ingress of the water.

The first and greatest difficulty that presented itself was the portion blown out by the barge in front of the river bank, and below low water, inasmuch as the soil was very much broken up and disintegrated over a large area, and the time during which puddling could be done was exceedingly limited.

It may be here mentioned that an erroneous impression prevailed among some persons present that it would be necessary to dig out this portion to a good bottom, in the usual manner of commencing the construction of a river wall, and the author had much difficulty in persuading them that immediate puddling of the fissures and broken ground below low-water mark was the only hope of succeeding, inasmuch as the cutting a grip would have occupied all the precious time employed in filling up. This puddling was most important in order to prevent percolation, the danger most necessary to be averted. When the navvies arrived from Crossness, they were immediately set to continue this important part of the work, and also the filling of the actual gap. It required some little time to arrange the number of men to advantage, but, being accompanied by able superintendents, they were soon allotted to their separate works of digging clay—wheeling it to the spot, and carrying water for the punning, where the clay was well worked with iron punners.

While the puddling, &c., was being vigorously carried on by this large force of men, the military arrived, commanded by General Warde and Colonel Hawkins, R.E. The difficulty of immediately rendering available, without confusion, the labor of all these men in so small a compass and on the spur of the moment may readily be imagined. With the greatest promptness, Colonel Hawkins adopted the suggestions offered him by the author, as to the method of proceeding. Several barrow roads were laid leading to the gap, numbers were employed in digging and loosening earth, filling and wheeling. The number of implements available for the use of the soldiers was, of course, limited; but, nothing daunted, they were formed into lines between the barrow roads, and passed from hand to hand towards the gap the lumps of earth and clay dug up by those at the back, the whole of the clay and earth for that purpose having to be brought from a distance of 60 or 70 yards by the barrow roads, and by hand, the soldiers passing lumps from one to another for this distance, which, when deposited in place, were immediately punned down perfectly solid. Having to deal with some 20 feet head of water, it was necessary to extend the width of the dam at the base, which absorbed an incredible amount of earth, the width of the breach being 130 feet. When the tide had reached and filled the front hole, it was found that the level of the water was within 2 feet or 3 feet of the top of the progressing work. The tide rising very rapidly, fears were entertained that sufficient soil could not be obtained to enable the work to keep ahead of the tide. At this juncture, the military produced a quantity of bags used for making sand-bag batteries, and a number of men were set to fill them with the soil at the back of the work. These bags were at first being thrown in indiscriminately, when the author directed that they should be laid at the back of the puddled face in the form of an arch on plan, to receive the horizontal pressure of the water. These bags were laid in courses, as shown in diagram No. 5, and punned so as to come in perfect contact. By this means the bank could be raised of sufficient strength with about one-half the material, and the disposition of the

men was so arranged as not to interfere with the other parts of the work. In this way about 3000 bags were used, and it was satisfactory to find they answered the purpose admirably; but even with this assistance, the tide was following the work very closely.

An alarm was now raised that the water was coming in, and it became apparent that there was considerable percolation under the dam —probably through the broken ground upon which so much labor had been bestowed in puddling—and making its appearance many yards at the back of the work, it was difficult to arrive at the treacherous point. This was most disheartening by the knowledge that a small stream would soon increase in newly made earthwork and undermine the whole. The exertions were redoubled, but it is feared that these would have proved of no avail, but for the timely settlement of the structure and consequent compression of the substrata. By this providential circumstance the leak was staunched, so that the settlement, apparently a source of great apprehension, proved really a matter for congratulation. Sole attention was now turned to raising the bank and protecting the face from the wash caused by passing steamers. Timber breakwaters were hastily constructed and floated in front of the work, and this in a great measure protected it from being undermined. By half-past one the tide was at its highest, and the bank was but a few inches above it; the structure successfully withstood the pressure of the water, but it was evident to all that the backing up must be continued before the danger was past, and the men, therefore, worked on until the tide had far receded. A large staff of men continued the operations throughout the night of Saturday.

On Sunday morning the bank was found to have settled some four feet, and, in consequence of high wind from the east and a heavy sea running, threatening to undermine the works, the author telegraphed to General Warde, Commandant at Woolwich, for 500 sappers and miners, who arrived in time to reinstate the dam. The whole of the past month has been occupied in restoring the wall to its original condition, and it is now as secure as any other portion of the embankment.

Breaches of the river wall reclaiming the marshes from the river Thames have been very frequent in times gone by. These have not arisen from causes similar to the one under consideration, but from high tides, defective sluices, and even rat-holes. In 1527 the river made an irruption at Plumstead and Erith, and so much land was submerged that it was not all regained until 1590, a matter of sixty-three years. This breach occurred within half a mile of the present one, and there are now existing traces of the inland embankments by which it was reclaimed piecemeal. In the time of Henry the Eighth, the marshes of Plumstead and Lesnes, now the Woolwich practicing ground, were submerged by the water coming in from the Erith breach. But the most recent, as well as the most important, was the Dagenham breach, which occurred in 1707, at a point exactly opposite the southern or fall works of the London sewerage. Continued attempts to stop this breach were made for eight years, but without suc-

cess, when Captain Perry undertook to reclaim it. At this time the breach is stated to have been on one occasion 50 feet below low water, or seventy feet below high water, caused by the ingress and egress of the flood and ebb tides. Captain Perry, it is stated, employed three hundred men for five years before he succeeded in stopping this breach, making thirteen years in all, during which time an immense quantity of the marshes were washed into the river, greatly obstructing the navigation of that important highway. The means he adopted were, first, forming sluices in the river wall to reduce the scour by allowing freer access to the water, and after so doing he drove dove-tailed or grooved piles from either side of the breach, protecting them as he went on with clay. The increased scour caused by this impediment threatened to deepen the channel so as to be beyond the reach of piles, and if the depth above stated was correct, it would have been impossible to have succeeded by this method; so the inference is that he chose a shallower portion of the breach; certain it is that he did succeed, although at a ruinous cost.

The Dagenham breach began with the failure of a sluice which had been allowed to get out of repair, and quickly extended from a gap of fourteen feet, and ultimately led to the obliteration of a thousand acres of land. But that was not all; about one hundred and twenty acres were actually washed away into the bed of the river by the flow of sullage, and the soil so washed formed a bank about a mile in length, reaching half-way across the river.

Perry in his work on Dagenham breach proceeds to explain how this sullage, driven into the river, was deposited at the mouth of the breach, and above as well as below it, in the reaches of the Thames. He remarks that the deposit had been particularly detrimental to Erith Reach; and that even in Woolwich Reach, as he had been informed, the depth of water was lessened. All breaches, he observes, must be attended with a considerable flow of sullage into the river. After mentioning breaches that had occurred before his time, including one in the levels of Dagenham Beam, not three years and a half since, and several near Dagenham since he had been concerned there, he says, he attributes all such breaches, not to any damage from the tides washing down or running over the tops of the banks or wells, but to the bad workmanship, decay, or defect of the sluices or trunks which are made for the drain of the levels, &c., and he alludes to sluices made of wood as a prevailing custom in England, and as generally insecure and unskilfully placed. He recommends, therefore, a law to oblige all sluices on the banks of the Thames to be made with stone, cemented with tarras. The reasons why they have not been made so, he thinks, are, first, that men in England are not very willing to depart from the way of their fathers; and, secondly, the matter of foundations. He argues, however, that if the foundations were constructed after the manner of buildings in Holland, the sluices might be formed of stone, or a sort of brick, as in Holland and Flanders, and might endure thousands of years.

The greater portion of the land bordering on the Thames, including

the south of London, indeed from Richmond to the Nore, is below the level of high water, and reclaimed by walls varying but little in their construction, the general character of which is an embankment, the face of which is puddled with clay to a slope of $2\frac{1}{2}$ to 1, and protected from the wash of the sea by a stone face. In some cases where the steepness of the bank necessitates a greater slope, the face is stepped, and at each step a row of stakes driven to keep the stone facing in place. In constructing these walls, a grip about 6 feet deep and 6 feet wide is cut into the marsh to be reclaimed on the site of the wall, and puddled before the bank is made to prevent percolation. These walls and the necesssary sluices for drainage require careful watching, for any portion failing would cause a catastrophe equal to the Dagenham or middle level inundation. The extent of these walls or embankments is very considerable, being about 300 miles in length.

It is a very remarkable circumstance that the marshes on the river side of the walls, still unreclaimed and termed "salt marshes," are invariably at a level of high water, whereas the land reclaimed is generally 5 feet or 6 feet below that level. Whether the constant action of the tide raises the land subjected to it, or whether the absence of that influence allows the level of the marshes to subside, or whether it is due to both these circumstances, is a fit subject for discussion, but, be it as it may, there is no question of the fact that they do so exist.

Another material point for discussion is furnished by the supposition that failure had attended the attempt to stop the recent breach, and that the waters had regained possession of their old territory, some seven feet deep at high water over an area of from 3000 to 4000 acres. Assuming this to be the case, the breach would be rapidly widened and deepened, and, were the old system adopted, the reclamation would occupy many years. It would be a work of from three to four times the magnitude of the Dagenham reclamation; and on the authority of Lambard, the land inundated by the breach which occurred in 1627 near the recent breach, as before noticed, was not all reclaimed in sixty-three years.

For the Journal of the Franklin Institute.

Limes, Cements, Mortars, and Concretes. Collected from the observations and experiments of Generals Gilmore and Totten, U. S. A., and MM. Vicat, Chatoney, Rivot, and Dupont. By Chas. H. Haswell, Civil and Marine Engineer, N. Y.

(Continued from vol. xlix, p. 367.)

No. 2.

Calcareous Mortar.—Being composed of one or more of the varieties of lime or cement, natural or artificial, mixed with sand, will vary in its properties with the quality of the lime or cement used, the nature and quality of sand, and the method of manipulation.

Mortar.—Lime, 1; clean sharp sand, 2·5. An excess of water in slaking the lime, swells the mortar, which remains light and porous, or

shrinks in drying; an excess of sand destroys the cohesive properties of the mass.

It is indispensable that the sand should be sharp and clean.

Turkish Plaster, or Hydraulic Cement.—100 lbs. fresh lime reduced to powder, 10 quarts linseed oil, 1 to 2 ounces cotton. Manipulate the lime, gradually mixing the oil and cotton, in a wooden vessel, until the mixture becomes of the consistency of bread-dough.

Dry, and when required for use, mix with linseed oil, to the consistency of a paste, and then lay on in coats.

Exterior Plaster or Stucco.—1 volume of cement powder to 2 volumes of dry sand.

In India, to the water for mixing the plaster is added 1 lb. of sugar, or molasses, to 8 Imperial gallons of water, for the first coat, and for the second or finishing, 1 lb. sugar to 2 gallons water.

Powdered slaked lime and Smith's forge scales, mixed with blood in suitable proportions, make a moderate hydraulic mortar, which adheres well to masonry previously coated with boiled oil.

The plaster should be applied in two coats laid on in one operation, the first coat being thinner than the second. The second coat is applied upon the first, whilst the latter is yet soft.

The two coats should form one of about $1\frac{1}{2}$ inches in thickness, and, when finished, it should be kept moist for several days.

This process may be modified by substituting for the first coat a wash of thick cream of pure cement applied with a stiff brush just before the plaster is laid on.

When the cement is of too dark a color for the desired shade, it may be mixed with white sand in whole or in part, or lime paste may be added until its volume equals that of the cement paste.

Khorassar, or Turkish Mortar, used for the construction of buildings requiring great solidity, $\frac{1}{3}$ powdered brick and tiles, $\frac{2}{3}$ fine sifted lime. Mix with water to the required consistency, and lay on layers of 5 and 6 inches in thickness between the courses of brick or stones.

Interior Plastering.—The mortars used for inside plastering are termed Coarse, Fine, Gauge or hard finish, and Stucco.

Coarse Stuff.—Common lime mortar, as made for brick masonry, with a small quantity of hair; or by volumes, lime paste (30 lbs. lime) 1 part, sand 2 to $2\frac{1}{2}$ parts, hair $\frac{1}{8}$ part.

When full time for hardening cannot be allowed, substitute from 15 to 20 per cent. of the lime by an equal proportion of hydraulic cement.

For the second or "brown coat," the proportion of hair may be slightly diminished.

Fine Stuff, (lime putty.)—Lump lime slaked to a paste with a moderate quantity of water, and afterwards diluted to the consistency of cream, and then allowed to harden by evaporation to the required consistency for working.

In this state, it is used for a "slipped coat," and when mixed with sand or plaster of Paris, it is used for the "finishing coat."

Gauge Stuff, or hard finish, is composed of from 3 to 4 volumes

fine stuff and 1 volume plaster of Paris, in proportions regulated by the degree of rapidity required in hardening; for cornices, &c., the proportions are equal volumes of each, fine stuff and plaster.

Stucco is composed of from 3 to 4 volumes of white sand to 1 volume of fine stuff, or lime putty.

Scratch Coat.—The first of three coats when laid upon laths, and is from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in thickness.

One-coat Work.—Plastering in one coat without finish, either on masonry or laths, that is, *rendered* or *laid.*

Two-coat Work.—Plastering in two coats is done either in a *laying coat and set*, or in a *screed coat and set.*

The *screed coat* is also termed a *floated coat.* *Laying* the first coat in two-coat work is resorted to in common work instead of *screeding*, when the finished surface is not required to be exact to a straight-edge. It is laid in a coat of about $\frac{1}{2}$ an inch in thickness.

Except for very common work, the laying coat should be *hand-floated.*

The firmness and tenacity of plastering is very considerably increased by hand-floating.

Screeds are strips of mortar 6 to 8 inches in width, and of the required thickness of the first coat, applied to the angles of a room, or edge of a wall and parallelly, at intervals of 3 to 5 feet all over the surface to be covered. When these have become sufficiently hard to withstand the pressure of a straight-edge, the interspaces between the screeds should be "filled out" flush with them so as to produce a continuous and straight, even surface.

Slipped Coat, is the smoothing off of a brown coat with a small quantity of lime putty, mixed with 3 per cent of white sand, so as to make a comparatively even surface.

This finish answers when the surface is to be finished in distemper, or paper hangings.

Hard Finish.—Fine stuff applied with a trowel to the depth of about $\frac{1}{8}$th of an inch.

ESTIMATE *of Labor and Materials for* 100 *square yards of Lath and Plaster.*

MATERIALS.	Three Coats Hard-finished Work.		Two Coats Slipped Work.	
Lime,	4 casks,	$4·00	3⅓ casks,	$3·33
Lump lime for fine stuff,	⅔ "	·85		
Plaster of Paris,	½ "	·70		
Laths,	2000	4·00	2000	4·00
Hair,	4 bushels,	·80	3 bushels,	·60
Common sand,	7 loads,	2·00	6 loads,	1·80
White "	2½ bushels,	·25		
Nails,	13 pounds,	·90	13 pounds,	·90
Mason's labor,	4 days,	7·00	3½ days,	6·12
Laborer,	3 "	3·00	2 "	2·00
Cartage,		2·00		1·20
Cost of 100 yards,		$25·50		$19·95

Concrete or Beton, is a mixture of mortar, (generally hydraulic,) with coarse materials, as gravel, pebbles, stones, shells, broken bricks, &c. Two or more of these materials, or all of them, may be used together. As lime or cement paste is the cementing substance in mortar, so is mortar the cementing substance in concrete or beton. The original distinction between cement and beton was, that the latter possessed hydraulic energy, whilst the former did not.

Hydraulic.—1½ parts hydraulic lime measured when unslacked, 1½ parts sand, 1 part gravel, 2 parts of a hard limestone broken.

This mass contracts ⅛th in volume. Fat lime may be mixed with concrete, without serious prejudice to its hydraulic energy.

Various Compositions of Concrete.—Forts Richmond and Tompkins, U. S.

Hydraulic.—308 lbs. cement = 3·65 to 3·7 cubic feet of stiff paste. 12 cubic feet of loose sand = 9·75 cubic feet of dense.

For Superstructure.—11·75 cubic feet of mortar as above, and 16 cubic feet of stone fragments.

In the foundations of Fort Tompkins, about one-twelfth of its volume was composed of stones from ¼ to ¾ of a cubic foot in volume, rammed into the wall as the concrete was laid.

Sea Wall.—Boston Harbor.

Hydraulic.—308 lbs. cement, 8 cubic feet of sand, and 30 cubic feet of gravel. The whole producing 32·3 cubic feet.

Superstructure.—308 lbs. cement, 80 lbs. lime, and 14·6 cubic feet dense sands. The whole producing 12·825 cubic feet.

TOTAL *Cost of Labor and Materials Expended in laying Concrete Foundation at Fort Tompkins, during the year* 1849.

Labor.

Wages of sub-overseer, 42·2 days at $2 per day,		$ 84·40
" mason, setting planks 82·8 days at $2 per day,		165·60
" laborers (assisting), 153·6 days at $1 per day,		153·60
" laborers transporting and ramming concrete, 2,971·8 days at $1 per day,		2,971·80
Total cost of labor,		$3,375·40

Materials.

4,096 casks cement at 85 cents,	$3,481·60		
12,288 " sand at 3 cents,	386·64		
20,480 " broken stone at 8 cents,	1,638·40		
		$5,488·64	
Total cost of labor and materials,			$8,864·04
Total number of cubic yards of concrete laid, excluding the stone masses rammed in,			3,606¼
Cost per cubic yard of pure concrete,			2·46
Deduct for stone masses rammed in,			·20
Cost per cubic yard as laid,			2·26

COST *of Masonry, of various kinds, per cubic yard, and the volume of Mortar required for each.—(General Gilmore, U.S.A.)*

MASONRY.	Volume of Mortar.	Lime required, no cement used.	Cement required, no lime used.	Difference of cost of Masonry with cement mortar and lime mortar.	COST.	
					Lime mortar.	Cement mortar.
	Cu. ft.	Bbls.	Bbls.	$ cts.	$ cts.	$ cts.
Rough, in rubble or gravel, from $\frac{1}{8}$ to $\frac{1}{10}$ cubic foot in volume,	10·8	·565	1·22	·90	4·10	5·
Blocks, large and small, not in courses; joints hammer-dressed,	8·1	·423	·92	·62	7·	7·62
Large masses; headers and stretchers dovetailed; hammer-dressed; beds and joints laid close,	1·	·05	·11	·08	9·	9·08
Ordinary; courses 20 to 32 in size,	1·5	·08	·17	·12	5·70	
Ordinary; courses 12 to 20 in size,	2·	1·05	·22	·16	2·19	
Brick,	8·	·42	·90	·66	5·70	6·20
Concrete, good,	11·	·54	1·75	1·21	2·19	3·20
" medium,	9·	·41	1·06	·65	1·56	2·21
" inferior,	8·	·37	·97	·60	1·45	2·05
Rubble, without mortar,					3· to	3·30

Cost of materials assumed as follows: Cement, $1·20 per barrel; lime, $1; bricks, $4·25 per M; sand and gravel, 80 cents per ton; granite spalls, 55 cents per cubic yard; labor, $1 per day.

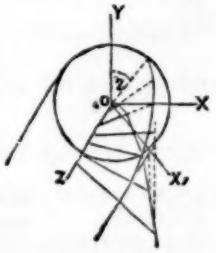
For walls less than 2 feet in thickness the cost is increased.

(To be continued.)

For the Journal of the Franklin Institute.

Intersection of the Joints of an Oblique Bridge with the Plane of the Face in the English System.

The joints* are warped surfaces subjected to the three conditions that the straight lines generating them shall pass through the axis, be perpendicular to it, and pass through helices drawn on the soffit.



The equations of this line then are $x = y \text{ tang } v$, $z = z$, those of the helix are $x^2+y^2=r^2$, $z=c(v-\eta)$. The equation of the surface then (combining the above equations and eliminating v) is

$$z+c\eta = c \text{ tang}^{-1}\frac{x}{y}, \quad . \quad . \quad . \quad (1.)$$

The equations of the plane of the face are $z=ax$, y indeterminate. Combining this with the equation of the surface to determine their intersection, we have

* Vide Buck's Oblique Bridges.

its projection on XY, $ax + c\eta = c \operatorname{tang}^{-1} \frac{x}{y}$. Calling $\frac{a}{c} = b$, we have

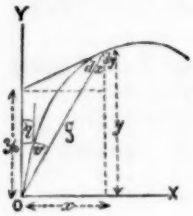
$$bx + \eta = \operatorname{tang}^{-1} \frac{x}{y}, \quad . \quad . \quad . \quad . \quad . \quad (2.)$$

If we substitute $\operatorname{tang}^{-1} \frac{x}{y} = v$, we have $bx + \eta = v$, from which the curve may be readily constructed; and since the increment of v is proportional to that of x, the curve is the quadratrix of Dinostratus.

If we wish the equation in the plane of the face, we readily obtain it by substituting $y = y_1$, $x = x_1 \cos a$.

In equation (2) b evidently depends only on the form and dimensions of the arch, while η varies in the different joints.

Theorem.—In a given arch the subtangent for equal values of ρ is independent of the position of the joint, that is of η.



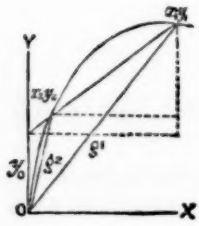
Proof. $\frac{dy}{dx} = \frac{y - y_0}{x}$ by similar triangles, or $y_0 = y - x\frac{dy}{dx}$, differentiating (2) we have

$$b\,dx = \frac{d\left(\frac{x}{y}\right)}{1 + \frac{x^2}{y^2}} = \frac{y\,dx - x\,dy}{y^2 + x^2}$$

multiplying out $by^2dx + bx^2dx = ydx - xdy$ or $x\frac{dy}{dx} = y - b(x^2 + y^2)$;

hence, $y_0 = y - x\frac{dy}{dx} = b(x^2 + y^2)$ or since the radius vector $\rho = \sqrt{x^2 + y^2}$,

$y_0 = b\rho^2$. This theorem is due to De la Gournerie who published a geometrical demonstration of it in the *Annales des Ponts et Chaussées*. It is practically applied thus: Since ρ is the same for all points of the intrados, calling this distance r, tangents to all the joints at the intrados intersect the axis of Y at br^2 from the origin.



Problem.—Is the intercept (on the axis of Y) of a line cutting the joint at ρ_1 and ρ_2 independent of η?

Solution.—Let x_1y_1, x_2y_2 be the co-ordinates of the points distant ρ_1 and ρ_2 from the origin. We have $\frac{x_1 - x_2}{y_1 - y_2} = \frac{x}{y_2 - y_0}$, multiplying out

$x_1y_2 - x_1y_0 - x_2y_2 + x_2y_0 = x_2y_1 - x_2y_2$ or $y_0 = \frac{x_1y_2 - x_2y_1}{x_1 - x_2}$, but $x_1 = \rho_1 \sin v_1$, $y_1 = \rho_1 \cos v_1$, $x_2 = \rho_2 \sin v_2$, $y_2 = \rho_2 \cos v_2$, substituting

$$y_0 = \rho_1\rho_2 \frac{\sin v_1 \cos v_2 - \cos v_1 \sin v_2}{x_1 - x_2} = \rho_1\rho_2 \frac{\sin(v_1 - v_2)}{x_1 - x_2},$$

but since x_1y_1 and x_2y_2 are on the curve of the joint $v_1 = bx_1 + \eta$, $v_2 = bx_2$

$+\gamma$; hence $y_0 = \rho_1 \rho_2 \dfrac{\sin b(x_1 - x_2)}{x_1 - x_2}$, calling $x_1 - x_2 = z$ we have

$$y_0 = \rho_1 \rho_2 \frac{\sin bz}{z}, \quad . \quad . \quad . \quad (3.)$$

since z evidently varies with γ, that is, $x_1 - x_2$ is different for different joints; hence y_0 will vary. There is one exception, when z is infinitesimal or $x_1 - x_2 = dx$, since then $\dfrac{\sin bdx}{dx} = b$ independent of dx. This is evidently the case of the tangent, and as here $\rho_1 = \rho_2$, we have $y_0 = b\rho^2$ as previously proved.

Buck, in his work on oblique bridges, speaks of this problem, but does not attempt an analytical proof. He made the geometrical construction on a large scale, and found y_0 independent of γ. His error arose from this, that in an ordinary bridge the pitch c of the spiral is very great, and $b = \dfrac{a}{c}$ very small; hence sin bz is so nearly equal to bz as to be indistinguishable in a drawing, and only becoming evident from the superior accuracy of analysis.

N. B. y_0 in practice is negative, but it is here taken positive for simplicity, as it does not alter the proofs.

MECHANICS, PHYSICS, AND CHEMISTRY.

For the Journal of the Franklin Institute.

Work and Vis-viva. By De Volson Wood.

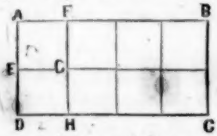
If I make any reply to the last article of Mr. Nystrom upon the subject under discussion, it must necessarily be upon some of the important points which I have previously omitted to discuss. I have no desire to mention them, for their *principles* are entirely foreign to our subject, and they are so elementary that it seems as if we ought not to be obliged to condescend to their discussion when treating of mechanical problems; but as I do not wish to be considered "unkind" on account of a partial treatment of the question, I will now notice them.

I have noticed several times that his views of multiplication are very different from mine, and it will be evident to the reader that one of us holds to views extremely faulty. For instance, he says, page 57, "When a quantity is multiplied by another quantity, the product becomes a third quantity, different from the two first." And again, "If two square feet be multiplied by a *thickness* of three linear feet, the product will be six cubic feet."

Now, I hold that, according to true logic, it is *impossible* to multiply one concrete number by another concrete number, and that every arithmetical process may be clearly analyzed without involving any such hypothesis. "But," says the objector, "do you not multiply linear

feet by linear feet to make square feet?" I say no, and proceed to analyze as follows:

To find the number of square feet in the rectangle A B C D, I have simply to find how many times it contains one square foot. We may form our unit by taking one foot from D on each of the lines A D and D C, and completing the square D E G H. Now, if A D is two linear feet, then will the rectangle A D H F contain *two times one square foot*, or two square feet. (Observe that it is TWO times, not TWO FEET *times*.) Then if A B contains four linear feet, the rectangle A C will contain *four times two square feet*, or eight square feet. This is the logic, and nowhere have we multiplied linear feet by linear feet. So to get cubical contents, we commence with our cubical unit, which is one cubical foot or inch, as the case may be, and determine each time the *abstract* multiplier from the linear measure. This process is so evident that I need not dwell upon it. Admit that multiplication can be performed by addition, and we must admit that the *true multiplier* is an abstract number, and the product is of the same kind as the multiplicand. Hence, if *power* is correctly represented by a plane surface, and *time* by a straight line, and *work* by a volume, it appears that work is not the product of power by time; for if we multiply an area (power) by any number, (the *number of units* in the time,) we get an area for the result. But if power be correctly represented by a unit of volume, then a repetition of it will give another volume, or work.



Now, I do not object to the *illustrations* which he has made, if they are simply used to *represent* the things to the eye; but if they are made the basis of a logical argument, it should be shown that they have the same relation to each other as the things which they represent. Popularly speaking, the illustration is good, because we say in common language that length by breadth gives area, and area by thickness gives volume; but such is not the teaching of true science—of true logic.

So I do not wish Mr. Nystrom to infer, as he seems to on page 57, that when $T = 1$, time disappears from the formula. I do not wish it to. I cannot tell whether he wishes it to or not, for on page 326, vol. xlviii, he says at least twice in his own definition, that the unit of time is involved. It is implied on page 359 of the same volume. It is admitted on page 183, vol. xlix, when he says the English unit for power is 33,000 pounds raised one foot *per minute*; and in the three heterogeneous definitions which immediately follow the above, it may be inferred or denied at pleasure, while in his last article, page 57, he says, "Power $= \frac{1}{2} F v \times 1$, *the abstract number*." If, as Mr. Nystrom says, the products of two quantities becomes a third quantity different from the two first, will he give us a rule which will enable us to determine the nature or kind of this third quantity? If so, perhaps he can tell what the product will be of five cubic feet by three square feet; of ten hogs by five bushels of corn; of fifteen green pumpkins by ten ripe squashes.

For the Journal of the Franklin Institute.

Strength of Cast Iron and Timber Pillers: A series of Tables showing the Breaking Weight of Cast Iron, Dantzic Oak, and Red Deal Pillars. By Wm. Bryson, Civ. Eng.

Continued from vol. xlviii, page 349.

Solid Uniform Square Pillars of Dantzic Oak, both Ends being Flat and Firmly Fixed.

Length or height of Pillar in feet.	Side of the square in inches.	Value of w in tons from formula $w=10{\cdot}95\frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{3}{4}c}$
6	11	4453·30	417·57	390·13
7	"	3271·81	"	383·87
8	"	2504·98	"	371·16
9	"	1979·24	"	360·52
10	"	1603·18	"	349·33
11	"	1324·95	"	337·74
12	"	1113·32	"	325·89
13	"	948·63	"	313·93
14	"	817·95	"	301·95
15	"	712·52	"	290 07
16	"	626·24	"	278·36
17	"	554·73	"	266·89
18	"	494·81	"	255·72
19	"	444·09	"	244·88
20	"	400·79	"	234·40
21	"	363·53	"	224·47
22	"	331·23	"	214·63
23	"	303·06	"	205·35
24	"	278·33	"	196·48
25	"	256·51	"	188·01
26	"	237·15	"	179·94
27	"	219·91	"	172·25
28	"	204·48	"	164·94
29	"	190·62	"	157·99
30	"	178·13	"	151·39

Solid Uniform Square Pillars of Dantzic Oak, both Ends being Flat and Firmly Fixed.

1	12	227059·2	496·94	496·12
2	"	56764·8	"	493·69
3	"	25228·8	"	489·70
4	"	14191·2	"	484·22
5	"	9082·36	"	477·35
6	"	6307·2	"	469·21
7	"	4633·87	"	459·94
8	"	3547·8	"	449·69
9	"	2803 2	"	438·62
10	"	2270·59	"	426·87
11	"	1876·52	"	414·59
12	"	1576·8	"	401·93
13	"	1343·54	"	389·02
14	"	1158·46	"	375·97
15	"	1009·15	"	362·90
16	"	886·95	"	349·90

(TABLE CONTINUED.)

Length or height of Pillar in feet.	Side of the square in inches.	Value of w in tons from formula $w = 10{\cdot}95\frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula $x = \frac{w\,c}{w + \frac{3}{4}c}$
17	12	785·67	496·94	337·05
18	"	700·8	"	324·41
19	"	628·97	"	312·03
20	"	567·64	"	299·97
21	"	514·87	"	288·26
22	"	469·13	"	276·93
23	"	429·22	"	265·98
24	"	394·2	"	255·43
25	"	363·29	"	245·29
26	"	335·88	"	235·55
27	"	311·46	"	226·22
28	"	289·61	"	217·29
29	"	269·98	"	208·75
30	"	252·28	"	200·59
6	13	8687·30	583·21	555·25
7	"	6382·51	"	545·80
8	"	4886·60	"	535·29
9	"	3861·02	"	523·86
10	"	3127·42	"	511·65
11	"	2584·65	"	498·79
12	"	2171·82	"	485·44
13	"	1850·55	"	471·71
14	"	1595·62	"	457·73
15	"	1389·96	"	443·61
16	"	1221·65	"	429·44
17	"	1082·15	"	415·33
18	"	965·25	"	401·34
19	"	866·32	"	387·54
20	"	781·85	"	373·98
21	"	709·16	"	360·72
22	"	646·16	"	347·78
23	"	591·19	"	335·20
24	"	543·00	"	323·01
25	"	500·38	"	311·18
26	"	462·63	"	299·77
27	"	429·00	"	288·77
28	"	398·90	"	278·18
29	"	371·87	"	267·99
30	"	347·49	"	258·20
SOLID UNIFORM SQUARE PILLARS OF RED DEAL, BOTH ENDS BEING FLAT AND FIRMLY FIXED.				
		$w = 7{\cdot}81\frac{D^4}{L^2}$		
1	12	161948·16	423·36	422·53
2	"	40487·04	"	420·06
3	"	17994·24	"	416·01
4	"	10121·76	"	410·48
5	"	6477·92	"	403·57
6	"	4498·56	"	395·44
7	"	3305·06	"	386·25
8	"	2530·44	"	376·15

(TABLE CONTINUED.)

Length or height of Pillar in feet.	Side of the square in inches.	Value of w in tons from formula $w=7{\cdot}81\frac{D^4}{L^2}$	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{3}{4}c}$
9	12	1925·28	423·36	363·42
10	"	1619·48	"	353·96
11	"	1338·41	"	342·18
12	"	1124·64	"	330·14
13	"	958·27	"	317·99
14	"	826·26	"	305·83
15	"	719·76	"	293·76
16	"	632·61	"	281·87
17	"	560·37	"	270·12
18	"	499·84	"	258·89
19	"	448·60	"	247·89
20	"	404·87	"	237·27
21	"	367·22	"	227·04
22	"	334·60	"	217·22
23	"	306·14	"	207·81
24	"	281·16	"	198·82
25	"	259·11	"	190·23
26	"	239·56	"	182·05
27	"	222·15	"	174·27
28	"	206·56	"	166·86
29	"	192·56	"	159·82
30	"	179·94	"	153·13

HOLLOW UNIFORM CYLINDRICAL PILLARS OF CAST IRON, BOTH ENDS BEING FLAT AND FIRMLY FIXED.

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $w=46{\cdot}65\frac{D^{3{\cdot}55}-d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of w.	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{3}{4}c}$
8	3	2	32		51·26	192·42	50·43
9			36	41·96			
10			40	35·08			
11			44	29·83			
12			48	25·73			
13			52	22·46			
14			56	19·80			
15			60	17·61			
16			64	15·78			
17			68	14·23			
18			72	12·91			
19			76	11·78			
20			80	10·79			
21			84	9·93			
22			88	9·18			
23			92	8·51			

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter, in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $w = 46{\cdot}65 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of w.	Value of e.	Calculated breaking weight in tons from formula $Y = \frac{w\,e}{w + \frac{1}{3}e}$
24			96	7·92			
25			100	7·38			
8	4	3	24		119·40	269·39	100·06
9			27		97·73		87·82
10			30		81·70		77·56
11			33		69·48		68·93
12			36	59·93			
13			39	52·30			
14			42	46·11			
15			45	41·01			
16			48	36·75			
17			51	33·15			
18			54	30·08			
19			57	27·43			
20			60	25·14			
21			63	23·14			
22			66	21·38			
23			69	19·83			
24			72	18·44			
25			75	17·21			
8	5	4	19·2		225·43	346·36	160·92
9			21·6		184·52		143·84
10			24		154·26		129·04
11			26·4		131·19		116·22
12			28·8		113·15		105·09
13			31·2		98·75		95·40
14			33·6		87·06		86·94
15			36	77·43			
16			38·4	69·38			
17			40·8	62·59			
18			43·2	56·79			
19			45·6	51·80			
20			48	47·48			
21			50·4	43·70			
22			52·8	40·37			
23			55·2	37·44			
24			57·6	34·82			
25			60	32·49			
8	6	5	16		375·06	423·33	229·26
9			18		307·01		208·11
10			20		256·66		189·23
11			22		218·27		172·46
12			24		188·26		157·58
13			26		164·31		144·36
14			28		144·86		132·63
15			30		128·82		122 18
16			32		115·44		112·88
17			34	104·13			
18			36	94·49			
19			38	86·19			
20			40	78·99			

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $w=46{\cdot}65\frac{D^{3{\cdot}55}-d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of w.	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{wc}{w+\frac{2}{3}c}$
21			42	72·70			
22			44	67·18			
23			46	62·29			
24			48	57·94			
25			50	54·06			
8	7	5·5	13·714		782·50	721·58	426·56
9			15·428		640·51		391·11
10			17·142		535·48		358·87
11			18·857		455·38		329·72
12			20·571		392·77		303·45
13			22·285		342·80		279·82
14			24		302·22		258·56
15			25·714		268·77		239·44
16			27·428		240·84		222·22
17			29·142		217·25		206·69
18			30·857		197·14		192·67
19			32·571	179·82			
20			34·285	164·81			
21			36	151·69			
22			37·714	140·15			
23			39·428	129·95			
24			41·142	120·89			
25			42·857	112·78			
8	8	6·5	12		1139·76	837·03	539·73
9			13·5		932·94		500·34
10			15		779·95		463·75
11			16·5		663·29		430·02
12			18		572·09		399·09
13			19·5		499·30		370·81
14			21		440·20		345·01
15			22·5		391·48		321·49
16			24		350·80		300·06
17			25·5		316·44		280·51
18			27		287·15		262·70
19			28·5		261·92		246·41
20			30		240·05		231·53
21			31·5		220·94		217·89
22			33	204·14			
23			34·5	189·28			
24			36	176·08			
25			37·5	164·27			
8	9	7·5	10·666		1582·15	952·49	656·16
9			12		1295·06		613·87
10			13·333		1082·68		573·85
11			14·666		920·74		536·35
12			16		794·14		501·43
13			17·333		693·11		469·31
14			18·666		611·06		439·35
15			20		543·44		411·52
16			21·333		486·97		386·10
17			22·666		439·27		362·68

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Calculated breaking weight in tons from formula $w=46{\cdot}65\frac{D^{3{\cdot}55}-d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of w.	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{3}{4}c}$
18			24		398·61		341·13
19			25·333		363·59		321·27
20			26·666		333·23		302·97
21			28		306·71		286·10
22			29·333		283·38		270·52
23			30·666		262·76		256·13
24			32		244·42		242·81
25			33·333	228·04			
8	10	8·5	9·6		2115·61	1067·94	774·65
9			10·8		1731·70		730·20
10			12		1447·74		687·55
11			13·2		1231·19		647·01
12			14·4		1061·91		608·76
13			15·6		926·81		572·86
14			16·8		817·10		539·29
15			18		726·67		508·00
16			19·2		651·16		478·88
17			20·4		587·38		451·82
18			21·6		533·01		426·71
19			22·8		486·19		403·38
20			24		445·58		381·73
21			25·2		410·12		361·64
22			26·4		378·93		342·97
23			27·6		351·36		325·63
24			28·8		326·84		309·53
25			30		304·93		294·46
8	11	9	8·727		3449·00	1539·38	1153·31
9			9·818		2823·16		1092·57
10			10·909		2360·19		1033·71
11			12		2007·16		977·25
12			13·090		1731·18		923·49
13			14·181		1510·94		872·60
14			15·272		1332·08		824·64
15			16·363		1184·66		779·60
16			17·454		1061·56		737·39
17			18·545		957·58		697·91
18			19·636		868·95		661·06
19			20·727		792·61		626·62
20			21·818		726·42		594·50
21			22·909		668·60		564·53
22			24		617·76		536·57
23			25·090		572·80		510·47
24			26·181		532·83		486·10
25			27·272		497·12		463·32
8	12	10	8		4392·96	1693·32	1313·57
9			9		3595·83		1251·35
10			10		3006·15		1190·41
11			11		2556·51		1131·31
12			12		2205·00		1074·46
13			13		1924·47		1020·12
14			14		1696·66		968·42

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in in inches.	No. of diameters contained in the length or height.	Value of w in tons from formula $w=46{\cdot}65\frac{D^{3{\cdot}55}-d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of c.	Calculated breaking weight in tons from formula $Y=\frac{w\,c}{w+\frac{1}{4}c}$
15			15	1508·90	169 3·32	919·45
16			16	1352·10		873·17
17			17	1219·66		829·54
18			18	1106·77		788·51
19			19	1009·55		749·92
20			20	925·23		713·69
21			21	851·60		679·69
22			22	786·84		647·77
23			23	729·57		617·83
24			24	678·67		589·74
25			25	633·18		563·36
8	13	11	7·384	5479·02	1847·26	1474·43
9			8·307	4484·82		1411·28
10			9·230	3749·36		1348·84
11			10·153	3188·55		1287·73
12			11·076	2750·13		1228·41
13			12	2400·26		1171·22
14			12·923	2116·12		1116·36
15			13·846	1881·94		1063·98
16			14·769	1686·38		1014·11
17			15·692	1521·20		966·76
18			16·615	1380·40		921·94
19			17·538	1259·14		879·51
20			18·461	1153·98		839·44
21			19·384	1062·14		801·62
22			20·307	981·37		765·94
23			21·230	909·95		732·30
24			22·153	846·46		700·58
25			23·076	789·72		670·67
8	14	12	6·857	6715·87	2001·19	1635·64
9			7·714	5497·24		1571·99
10			8·571	4595·74		1508·52
11			9·428	3908·34		1445·92
12			10·285	3370·96		1384·67
13			11·142	2942·10		1325·16
14			12	2593·82		1267·66
15			12·857	2306·78		1212·37
16			13·714	2067·07		1159·37
17			14·571	1864·60		1108·72
18			15·428	1692·01		1060·48
19			16·285	1543·38		1014·56
20			17·142	1414·48		971·37
21			18	1301·91		929·55
22			18·857	1202·91		890·32
23			19·714	1115·36		853·14
24			20·571	1037·54		817·95
25			21·428	967·99		784·61
8	15	12·5	6·4	9700·51	2645·81	2196·47
9			7·2	7940·29		2116·78
10			8	6638·17		2036·89
11			8·8	5645·27		1957·65

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Value of w in tons from formula $w = 46{\cdot}65 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of c.	Calculated breaking weight in tons from formula $Y = \frac{w\,c}{w + 3\,c}$
12	15	12·5	9·6	4869·06		1879·71
13			10·4	4249·61		1803·59
14			11·2	3746·56		1729·66
15			12	3331·94		1658·21
16			12·8	2985·71		1589·41
17			13·6	2693·26		1523·37
18			14·4	2443·97		1460·18
19			15·2	2229·28		1399.77
20			16	2043·10		1342·17
21			16·8	1880·50		1287·33
22			17·6	1737·51		1235·14
23			18·4	1611·05		1185·52
24			19·2	1498·64		1138·39
25			20	1398·18		1093·62
8	16	13·5	6	11594·01	2838·23	2397·96
9			6·75	9490·21		2318·24
10			7·5	7933·91		2237·82
11			8·25	6747·20		2157·54
12			9	5819·49		2078·09
13			9·75	5079·12		2000·01
14			10·5	4477·87		1923·73
15			11·25	3982·33		1849·57
16			12	3568·51		1777·76
17			12·75	3218·97		1708·45
18			13·5	2921·03		1641·79
19			14·25	2664·43		1577·73
20			15	2441·90		1516·36
21			15·75	2247·56		1457·66
22			16·5	2076·66		1401·56
23			17·25	1925·52		1348·00
24			18	1791·12		1296·90
25			18·75	1671·10		1248·22
8	17	14·5	5·647	13697·25	3030·66	2599·31
9			6·354	11211·80		2519·81
10			7·058	9373·18		2439·16
11			7·764	7971 20		2358·21
12			8·470	6875·16		2277·64
13			9·176	6000·52		2198·04
14			9·882	5290·19		2119·84
15			10·588	4704·75		2043·42
16			11·294	4215·87		1969·04
17			12	3802·92		1896·89
18			12·705	3450·92		1827·17
19			13·411	3147·78		1759·87
20			14·117	2884·88		1695·09
21			14·823	2655·29		1632·87
22			15·529	2453·38		1573·16
23			16·235	2274·82		1515·93
24			16·941	2116·10		1461·16
25			17·647	1974·25		1408·74
8	18	15·5	5·333	16017·99	3223·08	2800·45

(TABLE CONTINUED.)

Length or height of Pillar in feet.	External diameter in inches.	Internal diameter in inches.	No. of diameters contained in the length or height.	Value of w in tons from formula $w = 46{\cdot}85 \frac{D^{3{\cdot}55} - d^{3{\cdot}55}}{L^{1{\cdot}7}}$	Value of c.	Calculated breaking weight in tons from formula $Y = \frac{w\,c}{w + \frac{1}{3}c}$
9			6	13111·43		2721·35
10			6·666	10961·29		2640·71
11			7·333	9321·76		2559·38
12			8	8040·05		2478·03
13			8·666	7017·19		2397·26
14			9·333	6186·51		2317·53
15			10	5501·88		2239·24
16			10·666	4930·17		2162·69
17			11·333	4447·25		2088·09
18			12	4035·62		2015·69
19			12·666	3681·11		1945·50
20			13·333	3373·67		1877·68
21			14	3105·18		1812·27
22			14·666	2869·06		1749·25
23			15·333	2660·25		1688·64
24			16	2474·63		1630·42
25			16·666	2308·75		1574·52

(To be continued.)

On Chemistry Applied to the Arts. By Dr. F. CRACE CALVERT, F.R.S., F.C.S.

From the London Chemical News, No. 243.

(Continued from page 114.)

LECTURE IV.

ANIMAL FATTY MATTERS, the various processes for liberating them from the tissues in which they are contained. Their composition and conversion into soap. Composite candles. The refining of lard. *Cod liver*, *Sperm*, and other oils. *Spermaceti* and *wax*.

It will be quite out of the question for me to enter upon a general description of the properties and composition of fatty matters, as to do so would be to undertake far too wide a field of research. All that I can attempt in this lecture is to give an idea of their composition, and to describe some of their most recent applications to arts and manufactures.

The question of the source of the fatty matters in herbiverous animals has been the subject of a great number of scientific researches, but those of Baron Liebig, Dumas, Boussingault, Payen, and Milne Edwards have left no doubt that when the food of an animal contains a sufficient amount of fatty matter, this is simply extracted from the

food, and stored or consumed according to the animal's habits; that is to say, its consumption is in ratio to the activity of the animal; thus, an animal in a state of great activity is comparatively thin, but when confined in a pen or stall it quickly fattens. These gentlemen also proved that when the food is deficient in fatty matters, a portion of the amylaceous or saccharine matter becomes converted into fatty matter. The most decisive experiments on this head were made by Mr. Milne Edwards, who found that when bees were confined under a glass shade, with no food but honey, they converted the greater portion of it into wax. Notwithstanding these proofs, however, chemists found it difficult to understand how substances so rich in oxygen as amylaceous ones becomes converted into a class of matters containing so little of that element, but Baron Liebig has lately published a paper which has partially solved this problem, showing that animals give off during respiration a larger amount of oxygen than is contained in the air inspired, which excess must be derived from certain organic substances circulating in the blood. Fatty matters may be classed under two heads, viz: vegetable and animal. The first are generally composed of a solid called margarine, and a liquid called oleine. The latter generally contains three substances, viz: two solids, stearine and margarine, and one liquid, oleine. I say generally, because their are exceptions: thus, in palm oil palmetine is found, in linseed oil, linoleine, in sperm oil, spermaceti, and in waxes several peculiar acids. Let us now examine the composition of some of the most abundant fatty matters found in animals. The knowledge of the composition of these substances, of suet for example, was most unsatisfactory until 1811, when my learned and eminent master, M. Chevreul, published his elaborate researches, by which he demonstrated the real composition of fatty matters in general, and that they might be considered as real organic salts. Thus, suet is composed of stearic, margaric, and oleic acid combined with the oxide of glyceryle. The three above-named acids he showed to be composed as follows:

	Stearic acid.	Margaric acid.	Oleic acid.
Carbon, . . .	68	34	36
Hydrogen, . . .	66	33	33
Oxygen, . . .	5	3	3
Water, . . .	2	1	1

Also that oxide of glyceryle, as it is liberated from the fatty acids, combines with water and forms glycerine. He further showed that when fatty matters were saponified, the change consisted in the substitution, for the oxide of glyceryle, of the oxide of sodium or soda in ordinary hard soaps, of the oxides of potassium and potash in soft soaps, of oxide of lime, baryta, or lead in insoluble soaps. You will easily conceive the pride of M. Chevreul when, forty years later, M. Berthelot effected the synthesis of the fatty matters, the analysis of which M. Chevreul had published in 1811. This he accomplished by heating in sealed tubes, at a temperature of 520° for several hours, one, two, or three equivalents of each of the above acids, with one equivalent of glycerine, leaving the mixture to cool, and then boiling

it in a vessel with water and lime, when the excess of fatty acids not combined during the experiment were removed by the lime, leaving the neutral fatty matter, which was dissolved by ether, and thus obtained in a state of purity. By this interesting series of researches, M. Berthelot has not only reconstituted neutral fatty matters, but showed that the oxide of glyceryle was triatomic; that is, that one equivalent of the oxide would neutralize three equivalents of the acid, whilst it required three equivalents of soda to produce a neutral stearate with three equivalents of stearic acid.

Stearic acid, 3 ($C_{68}H_{66}O_5$) Glycerine, $C_6H_8O_6$—4 HO.

Stearic acid, 3 ($C_{68}H_{66}O_5$) + Soda, NaO—3 HO.

In fact, the researches of this eminent chemist on the synthesis of organic substances have effected a complete revolution in the last few years in that branch of organic chemistry.

I shall now proceed to give you a rapid outline of the properties of these substances.

Stearic acid is a white crystalline substance, fusible at 158° F., soluble in alcohol and ether, insoluble in water, and saponified by alkalies.

Margaric acid is a solid crystalline substance, presenting the same properties as stearic, excepting that its fusing point is 140°.

Oleic acid is a fluid remaining in that state even at several degrees below the freezing point of water, and is also soluble in alcohol and ether, but not in water.

Glycerine, or the sweet principle of oils, was discovered in 1779, by Scheele, who extracted it in boiling oil of sweet almonds with oxide of lead, which, combining with the fatty acids, liberated the oxide of glyceryle, and this, in combining with water, formed glycerine. In consequence of the numerous applications of glycerine in medicine, the French have manufactured this substance on a large scale from the liquors in which they have saponified their fatty matters into soap; but the purest and most extensive supply is furnished by Price's Patent Candle Company. In the course of this lecture I will give you a description of its preparation as carried out at their works. Glycerine is a colorless, syrupy fluid, of sweet taste, and sp. gr. 1·28, highly soluble in water and alcohol, combining easily with hydrochloric, hydrobromic, benzoic, tartaric, &c., acids, forming neutral compounds. Diluted nitric acid converts it into glyceric acid; concentrated nitric acid into nitro-glycerine, or a substance exploding with violence by percussion, which has caused it to be proposed as a substitute for fulmintaing mercury by its discoverer, Professor Sobrero. The application in medicine of glycerine has been greatly extended by its highly hygrometric properties. Thus, bandages moistened with glycerine remain constantly moist, because the glycerine attracts moisture from the air as fast as it is lost by evaporation. It has also been found eminently useful in diseases of the eye and ear. Glycerine boils at 527°, but when distilled is partly decomposed into a peculiar oily fluid, of a noxious odor, called acroleine. M. Berthelot has succeeded, by fermentation, in converting glycerine into alco-

hol. Again, Mr. George Wilson, F.R.S., the talented director of Price's Patent Candle Company, has applied glycerine, with great success to the preservation of vegetable and animal substances. Another useful employment of glycerine is its substitution for water in gasometers, where the evaporation of the latter is a source of serious loss. Its addition to a soap solution increases the facility of forming soap bubbles to an extraordinary degree. In fact, by its aid bubbles of seven or eight inches diameter can be produced, exhibiting most beautiful purple and green colors, the beauty of which is greatly enhanced, as Mr. Ladd will show you, when illuminated by the electric light. To prepare this peculiar soap solution, the following proportions are stated to be employed: Distilled water, 5 ounces; soap $\frac{1}{8}$ of a drachm; glycerine, 2 drachms.

The extraction of the fatty matters of animals from the tissues enveloping them is a simple operation. The old process of doing this, technically called "rendering," consisted in introducing the suet into large iron pans and applying heat, which caused the fatty matters, by their expansion, to burst the cells confining them, and to rise to the top of the contents of the boiler, which were left to stand for a few hours, and the liquid fat was then run off. The organic tissues remaining with a certain amount of fat at the bottom of the boilers were removed and subjected to pressure so as to separate the rest of the fat, the organic tissues remaining behind being sold under the name of scraps for feeding dogs, &c. As this operation gives rise to noxious vapors, causing thereby great annoyance, other methods have been generally adopted. For instance, Mr. D'Arcet's, the leading feature of which is to place in a boiler say 350 lbs. of suet, with 150 of water, 15 of sulphuric acid, carrying the whole to the boil for some hours, when the sulphuric acid dissolves the organic matters and liberates the fatty ones, which are then easily separated from the aqueous fluid. Mr. Evrard's process appears preferable. He boils the fatty matters with a weak solution of alkali; or, in other words, he uses 300 lbs. of suet with half a pound of caustic soda dissolved in twenty gallons of water, carrying the whole to the boil by means of a jet of steam. Under the influence of the alkali the tissues are swollen and dissolved and the fat liberated. By these operations a better quality of fat is obtained and no nuisance is created. It is found advantageous to purify or bleach the above fatty matters by the following means. Mr. Dawson's process consists in passing air through the melted tallow, and Mr. Watson's in heating melted fatty matter with permanganate of potash. Both these processes, as you will perceive, are based on the oxidation of the coloring organic matter. Some tallow melters further clarify their tallow by adding 5 lbs. of alum in powder to 100 lbs. of melted tallow, which separates and precipitates any coloring matter. The white snowy appearance of American lard, which is rather deceptive to the eye than profitable, is obtained by thoroughly mixing by means of machinery, starch in a state of jelly with a little alum and lime, with the fatty matter, by which means two ends are attained—viz: the introduction of 25 per cent. of useless matter, and a perfect white-

ness from the high state of division of the same. The fatty matters from fish are generally obtained by boiling those parts of the fish containing them with water, when the fatty matters rise to the surface of thefluid, and one whale has been known to yield as much as a 100 tons of oil. According to M. Chevreul, the composition of whale oil is as follows:

Solid fats, . . .	{ Margarine, Cetine.
Liquid fats, . . .	{ Oleine, Phocenine.

together with a small amount of coloring matter, and of phocenic acid, which gives to whale oil its disagreeable color and odor. Many attempts have been made to sweeten whale oil by the use of weak caustic lye, milk of lime, sulphuric acid, and steam; but although a great improvement has been effected, the oil is still recognisable by its unpleasant odor. I have no doubt in my mind, from experiments made by my friend Mr. Clift, that fish oils might be obtained as sweet as vegetable oils, if proper means for their extraction were adopted. Allow me here to revert to animal fats, to show you that their comparative hardness or solidity, as shown by the following table, depends upon their relative proportions of stearine and margarine, or oleine:

	Stearine or Margarine.	Oleine.	Melting point.
Ox tallow, . .	75	25	111·0°
Mutton suet, . .	74	26	109·0
Hog's lard, . .	38	62	80·5
Butter (summer), .	40	60	86·2
Do. (winter), .	63	57	79·7
Goose fat, . .	32	68	79·0
Duck fat, . .	28	72	77·0

M. Pelouze proved some years ago that the rancidity of ordinary animal as well as vegetable oils is due to a fermentation; that is to say, that under the influence of the azotised principle associated with all fats, the fatty matters split into their respective fatty acids and glycerine, which in their turn undergo a further change, resulting in the production of volatile fatty acids, such, for example, in the case of butter, as butyric, caproic, capric, and caprolic acids; in the case of goat's milk, hirsic acid; of fish oil, phocenic acid. Further, M. Pelouze demonstrated that in the case of olive oil this change occurred a few hours after the crushing of the berries, the oil thereby coming in contact with the albuminous principles or ferment.

I shall now have the pleasure of calling your attention to some of the special applications which fatty matters receive. The first of these arises out of the action of alkalies upon these substances, the result of which is the conversion of an insoluble matter (oil) into a soluble one (soap). I shall not enter into minute details of this well known manufacture, but content myself with touching upon some of the most recent improvements. The usual mode of making soap is to add animal fats or vegetable oils to a weak lye, or caustic solution, carrying the mixture to the boil by means of steam pipes passing through the vessel above a false bottom, and keeping the whole in constant

agitation by means of machinery. During this operation the oxide of sodium replaces in the fatty matter the oxide of glyceryle, and when the lye is killed, that is to say when all its alkali is removed by the oil, a fresh or stronger lye is added, and these operations are repeated until the manufacturer considers that the matter is nearly saponified, which is easily judged of in practice. He then proceeds with a second series of operations, called salting, which have for their object to separate the glycerine and impurities from the soapy mass, and also to render the latter more firm and compact, in fact, to contract it. This is effected by treating it with stronger lye mixed with a certain quantity of common salt, and allowing it to stand for a few hours, so that the mass of soap may separate from the fluid containing glycerine, and other impurities. When the second series of operations are finished the clarifying or finishing process follows: this requires the use of still stronger lye and salt, which not only complete the saponification, but separate any remaining impurities; the semifluid mass of soap is then allowed to stand for twelve hours, when the soap is either run or ladled into large wooden moulds, and allowed to stand until quite cold. After standing for a day or so, the wooden frame is removed from the solid mass of soap, when it is divided into bars by means of a brass wire. The difference between *white curd* and *mottled* soap is caused by the addition to the fluid mass of soap of about four ounces of alum and green copperas to every 100 lbs. of soap, which gives rise to an alumina and ferruginous soap, which, on being diffused through the mass by means of agitation, mottles or marbles the mass when cool. When well prepared this is the most economical soap, as no large quantity of water can be introduced to weight it, because this would cause the separation of the mottling material from the soap. *Fancy soaps* are prepared in the above manner by the employment of a better quality of materials and the addition of various perfumes. *Rosin or yellow soap*, as its name implies, is one in which a portion of the fatty matters is replaced by rosin, which is added to the soap paste when there is but little aqueous solution of alkali left to dissolve it, so that the rosin can at once enter into the composition of the soap, instead of being dissolved in the alkaline lye and lost. Rosin soaps, nearly white, are now manufactured, owing to the discovery of Messrs. Hunt and Pochin, who have succeeded in obtaining nearly white rosins by distilling common rosin with the aid of superheated steam. *Silicated soaps* are much used in America, owing to their cheapness, which is due to the introduction of a certain amount of silicate of soda. *Transparent soap*, the method of making which was so long kept secret, is now known to be obtained by dissolving soap in alcohol and allowing a concentrated solution of it to cool slowly, when it is poured into moulds and allowed to solidify. One of the most useful and recent improvements in soap making is that which enables the manufacturer to produce what is called *glycerine soap*, which is characterized by the retention of the glycerine of the fatty matter. Its manufacture only occupies a few hours, instead of several days, as is the case with ordinary soap. It is prepared by employing 63 parts of fatty matter, 33

of water, and 5 of alkali, which are heated to a temperature of between 350° and 400°, for two or three hours, when the mass is entirely saponified, and then has only to run into moulds to be ready for the market. But the most important discovery connected with the saponification of fatty matters by means of alkali is that recently made by M. Mèges Mouries, for this gentleman has arrived at the remarkable result of saponifying fatty matter in the space of twelve hours, and, what is more extraordinary still, at natural temperatures. If we connect this fact with the one that caustic soda is now manufactured by tons, it appears highly probable that in a few years the fatty matters of Brazil and Monte Video, instead of being sent to this country as such, will be converted into soap there, and imported thence by us in that form. M. Mouries has discovered the fact that fatty matters are susceptible, under peculiar circumstances, of being brought into a globular state, and that when in that state they present new and peculiar properties. Thus, for example, fatty matters, when kept in a damp state, usually become rapidly rancid, whilst when in the globular state they may be kept for a very long period without undergoing that change. This peculiar state can be imparted to fatty matters by melting them at 130° and adding a small quantity of yolk of egg, bile, albuminous substances, or, what is best, a solution of alkali, composed of five to ten parts of alkali for every 100 parts oil, at the same temperature, agitating the whole for some time to bring the fatty matter into a globular condition. If at this stage the action of the alkali is continued and the temperature is raised to 140°, it is found that instead of the fatty matters requiring a long time to saponify, (as is usual even at a temperature of 212°,) the saponification is most rapid, because each globule of fatty matter offers an immense surface to the action of the alkali; and it is found that in two or three hours the whole of the fatty matters are converted into soap. In fact, saponification is so perfect that the mass of soap dissolves completely in water; and if the purpose is to liberate the fatty acids, this can be done at once by the addition of a little vitriol. The fatty acids produced by this comparatively cold saponification are so pure that, when subjected to pressure, the solid fatty acids have not the slightest odor, and fuse at the point of 138°. As to the oleic acid prepared by this process, instead of being brown, (as is usual with the commercial acid,) it is colorless and can be employed in manufacturing soap of good quality. When M. Mouries desires to make soap with the entire fatty matter, he acts at once upon the globular fatty mass by adding salt, which separates the soap from the aqueous fluid; it is then melted and run into moulds. Whilst speaking of the mode in which alkalies can be made to act upon fatty matters, I ought to state that M. Pelouze observed the curious fact that large quantities of fatty matters could be split into their respective elements, viz: fatty acids and glycerine, by heating them for some hours with a small quantity of soap. This discovery, as we shall presently see, has been taken advantage of in the manufacture of stearic candles.

Permit me to state that *soft soaps* differ from hard soaps mainly in

the substitution of potash for soda, and in the omission of the salting and clarifying processes, so that the soapy mass is not separated from the excess of water, and therefore after the fatty matter has been saponified by the alkali, the whole is evaporated to the required consistency. I cannot conclude better this hasty and imperfect sketch of the soap manufacture than by the following table of compositions, showing the per centages of the various elements in the following soaps:

Names of soaps.	Fatty acids.	Alkali.	Water.
Curd, . . .	62	6·0	32·0
Marseilles, . .	60	6·0	34·0
White, . . .	60	6·4	33·6
White cocoa, . .	22	4·5	73·5
Yellow rosin, . .	70	6·5	23·5
Calico printer's, .	60	5·2	34·8
Silk boiling, . .	57	7·0	36·0
Wool scouring, .	55	9·0	36·0
Soft, . . .	43	10·0	47·0
Theoretical, . .	63	6·4	30·6

As it is easy to introduce into soaps a much larger quantity of water than they should contain to render their employment economical, it behooves those which use large quantities in their manufacture to ascertain the extent of the moisture contained in soaps. This may be pretty accurately approximated to, by placing a quarter of an ounce, divided into thin shreds, upon a hob or other warm situation, and leaving it for several days, when it will lose nearly the whole of the water it originally contained, or about a third of its weight, if it does not contain an undue proportion. In many instances the proportions of alkali in soap may seriously affect its applicability. Thus I ascertained a few years since that the quality of soap best adapted to clear madder purples should not contain more than 5 per cent. of alkali, whilst for pinks, where it is necessary to remove any loose color which the mordants may have mechanically retained, a more active soap is required, viz: one containing from 6 to 7 per cent. of alkali.

(To be continued.)

For the Journal of the Franklin Institute.

Speed of Ships.

The brig *Los Amigos*, Captain Johnson, has made the run from Belize, Honduras, to the Port of New York in 14 days.

The brig *Nellie Antrim*, Captain Wallace, arrived at the port of New York, evening July 11, 1865, having made the round voyage out to Nuevitas and back, with a full cargo each way, in 30 days' time.

The clipper ship *Twilight*, Captain Holmes, left New York December 24, 1864, and arrived at San Francisco April 20, 1865, making the voyage at that season of the year in the short time of 117 days.

The steamer *Guiding Star*, Captain Berry, belonging to the New York Mail Steamship line, arrived at the port of New York Friday

July 28, 1865, having made the run from New Orleans in 5 days, 11 hours, and 30 minutes, the quickest passage on record between these two ports.

The steamer *Morro Castle*, Captain ———, and owned by Messrs. Spafford, Tileston, & Co., arrived at the port of New York July 5, 1865, having made the run from Havana in the remarkable time of 3 days and 15 hours. E.M.B.

On the Supposed Nature of Air prior to the Discovery of Oxygen.

By GEORGE F. RODWELL, F.C.S.

From the London Chemical News, No. 279.

Continued from vol. xlix, page 406.

XI. *Rise of Scientific Societies.*—Inasmuch as in the following papers we shall have frequently to allude to the labors of various scientific societies in connexion with the subject under consideration, and as, moreover, institutions of this nature have done much to further the progress of experimental philosophy, I conceive it will not be out of place here to give a short account of their rise, and of their effect on the progress of physical science.

Among the ancients there was no experimental philosophy; we read of a few isolated experiments—such as the electrical experiment of Thales, the proof of the materiality of air proposed by Anaximenes, and the magnetic experiment mentioned by Lucretius—but these were exceptions; men preferred to rely on the unaided intellect rather than to call in assistance from external sources; they preferred to give a theoretical explanation of a natural phenomenon, and to reason on that, all unproven as it was, as if it were a well established and absolute truth. Let any one read the "Physics" of Aristotle if he wishes to comprehend the tone of physical thought which prevailed among the ancients. Such a treatise is intolerable to a follower of the Baconian method; the long, dreary trains of reasoning, perpetually ramifying in all directions, and the continued proposal of one theory to support another, so divert the mind from the subject discussed, that it ultimately grasps the explanation with difficulty. Such a system has no solid basis; destroy one theory in any part of the explanation, and the whole mass of reasoning in a moment falls to the ground. When we remember that this was the scientific text-book for 2000 years, can it be wondered that the physical sciences are now almost new-born in the world?

Passing onward to this side of the Christian era, we find a manifest lessening of intellectual activity; the golden age of literature among the ancients had passed away. Greece for a long period had ceased to furnish writers of eminence; the Romans, tired of conquest, became indolent, luxury and corruption followed, and, as a consequence, enervation of intellectual power. Then came those uncivilized Northern races, which, in destroying the Roman empire, at the same time crushed all traces of learning; but that unyielding besom, while it

swept away a debased and impoverished literature, did also remove the causes which had conduced to its impoverishment.

From the time of the destruction of the Roman empire till the fifteenth century, science, in common with all other pursuits depending on mental energy, was utterly neglected. There could be but little learning during the Middle Ages. The priests were the most educated members of the community, and on that account they possessed immense power over the human mind, for on them devolved not only spiritual but also temporal teaching. But they were an ignorant class of men, and cared for nought but to uphold and maintain the dominion of their Church, and their own dominion over the minds of men. Their could be no scientific progress; for had not that Church, now dominant and supreme, condemned the study of physical science? had it not affirmed that the Aristotelian philosophy was sufficient for all purposes, and ruled that it alone should be followed? In the fifteenth century the power of the Church began to wane; Savonarola had arisen, and had waged war against the obsolute dominion of the hierarchy; Sarpi was soon to appear; a few had ventured to dispute the authority of Aristotle in physical matters, and had been punished for their freedom of thought. The human mind began to arouse itself after its long imprisonment, and to strive to burst asunder its fetters, for the Church had at first bound it captive with silken threads easy to be broken, but eventually they became fetters of steel. A yearning for intellectual progression was apparent, a desire to employ the long neglected attribute of reason; and now in that land in which more than a thousand years before learning had been almost blotted out, there arose a regenerated intellect—a new tone of thought; Italy was the cradle in which it gained vigor, and it passed out thence to civilize the whole world.

Among the greatest experimental philosophers of the Middle Ages, I may mention Roger Bacon,* Albertus Magnus, the Spanish philosopher Averröes, and Leonardo da Vinci. We may briefly refer to the first and last of these.

The sixth part of Bacon's "Opus Majus"† bears the title "De Scientia Experimentalis." The first chapter treats "of the utility of experimental science;" the last "of the dignity of the experimental arts." Throughout the work we find a strong advocacy of experiment as a guide to the intellect to assist it in arriving at the causes of unusual physical effects. No treatise at all comparable to this appeared during the Middle Ages—indeed, not until the publication of the "Novum Organum."

Leonardo da Vinci‡ is known to every one as a great painter, but it is not so generally known that he was a great mathematician, physicist, and engineer, and by no means an inferior musician. His phy-

* Born, 1214. Died, 1284.

† "Fratris Rogeri Baconis, Opus Majus." Ad Clementum Quartum. Ex M. S. Codice Dubliniensi cum aliis quibusdam collato, nunc primum edidit S. Jebb, M. D. Londini. 1733.

‡ Born, 1452. Died, 1519.

sical views are far in advance of those of either his own or the succeeding age; our chief knowledge of them is derived from some of his unpublished MSS., which are preserved in the King's library at Paris; many of these were translated into French by Venturi, and published in 1797.*

The following passage is written in the true spirit of inductive philosophy; indeed, no one who has read the "Novum Organum" can fail to be reminded of many of the similar passages therein:

"*Of Method.*—Theory is the general, practice the soldiers. The interpreter of the artifices of Nature is experiment. It never deceives; it is our judgement that sometimes deceives itself, because it expects results which experiment refuses. We must consult experiment, varying the circumstances until we have deduced general rules, for it alone can furnish reliable rules. But you ask me, Of what advantage are these rules? I answer that they guide us in the researches of Nature, and the operations of art. They prevent us from deceiving ourselves or others by promising ourselves results which we cannot obtain."

I may also mention a sentence bearing directly on our subject, in which we have proof of most advanced physical knowledge for the period, and which shows that Leonardo da Vinci was aware that fire is not elemental, and that it requires air for its sustenance—a theory, I need not say, wholly at variance with that maintained by his contemporaries:

"*Of Flame and Air.*—There is smoke in the centre of the flame of a wax candle, because the air which enters into the composition of the flame cannot penetrate to the middle of it. It stops at the surface of the flame, and condenses there; in becoming aliment of the flame, it is transformed into it, and leaves a void space which is filled successively by other air."

In the middle of the sixteenth century the Church armed itself with a new and powerful weapon to suppress free thought; this was the right which it assumed of prohibiting the printing and reading of certain books which were believed to inculcate injurious ideas. The first catalogue of prohibited books was published by Paul IV. in 1559. In it no less than sixty-one printers were condemned, and *all* works issuing from their presses were forbidden to be read. Theological treatises were not the only works submitted to examination; scientific works did not escape. Thus I find at the commencement of Baptista Porta's four books "De Aëris Transmutationibus," an order from the examiner allowing them to be printed, because, he writes, "in quibus nihil inveni, quod sit contra fidem, aut bonos mores."†

* "Essai sur les ouvrages physico-mathematiques de Leonard da Vinci, avec des fragmens tirés de les manuscrits." Par J. B. Venturi. Paris. An v. (1797.)

† The order is conveyed in the following form:

"Imprimatur, si videbitur R. P. M. Sacri. Pal. Apost.

"Cæsar Fidelis Vices-gerens.

"Iussu Reurendissimi P. F. Ludouici Ystella Sacri Palitij Magistri. Ego Alexander de Angelis Societatis Iesu, et Sacræ Theologiæ Professor, legi quatuor libros Meteororum Io. Baptistæ Portæ Neapolitani, in quibus nihil inveni, quod sit contra fidem, aut bonos mores, sed dignos eos indico qui in lucem prodeant, si ita videbitur ijs, quorum interest. Data in nostro Collegio Romano die 22 Novembris, 1608.—"Ego Alexander de Angelis qui supra."

Towards the end of the sixteenth century, we find a greater freedom of physical thought beginning to be apparent; many eminent men now arose. Among them may be mentioned Telesio, Aconcio, Nizzoli, our countryman Gilbert, Giordano Bruno, and Galileo, great and original thinkers, worthy to be reverenced in all ages, for they broke down the barriers which had so long protected the Aristotelian philosophy, and by so doing prepared the world for the change about to be effected by the cardinal and sovereign intellect of Francis Bacon. Giordano Bruno suffered at the stake for the too open expression of his views; Galileo was compelled to resign his lectureship at Pisa, because he proved the fallacy of Aristotle's theory in regard to the velocity of falling bodies; at a later date he was imprisoned for daring to promulgate the Copernican theory of the earth's motion. These were the last great efforts of the hierarchy to curb and restrain the workings of the human mind, the last acts of oppression to be practised by a long dominant Church.

Although the Aristotelian philosophy had long been falling into disrepute, no system at all comparable to it had been propounded, and it was not till the publication of Bacon's "De Augmentis Scientiarum," that it received its death-blow. Mankind was now taught to interrogate Nature, not by reason alone, but by reason aided by experiment; not by the use of the syllogism, but by induction. From this period commences the epoch of modern science.

A few literary societies appeared in Italy in the fifteenth century, but their formation was not encouraged. In 1468 Paul II. arrested the members of a literary society on the charge of introducing foreign superstitions. They were ordered to be tortured and imprisoned for a year.

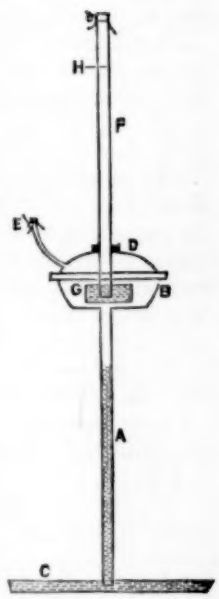
In the sixteenth century, societies became much more numerous; they existed, however, almost exclusively in Italy, and were generally devoted to the improvement of the Italian language, or to the study of the Platonic philosophy.

The first scientific society was established by Baptista Porta in the middle of the fifteenth century. It was called the "Academy of the Secrets of Nature," and consisted solely of men who had discovered something of importance in medicine or natural philosophy. From the name of the society it was believed that magic and illicit arts were practised by its members. Porta was summoned to appear at Rome, and commanded by Paul III. to discontinue the meetings of the society. While in Rome he was elected a member of the "Lyncean," a very celebrated academy, to which Galileo also belonged.

The first scientific society of importance was the Accademia del Cimento, established in Florence in 1657, by Duke Leopold of Tuscany. The object of this society was "to make experiments and relate them," and to ignore all theoretical matter. It proved worthy of its name "del Cimento," but, unfortunately for science, it endured only ten years, for Leopold was created a cardinal in 1667, and by leaving Florence withdrew his direct patronage from the society. During the ten years of its existence, however, a large number of ex-

periments were made by its members. A volume containing an account of them was published by the Secretary in 1667,* from which we extract the following relating to the subject under consideration.

In the early part of the work we find the description of a method of determining the comparative amounts of moisture in the air of different localities. The apparatus employed for the purpose was somewhat similar in form to the "ice calorimeter" of Lavoisier and Laplace. It consisted of a hollow metal cylinder lined inside with cork, open above, and terminated below by a cone. Ice was placed within it, and there was a lateral tube communicating with the interior for allowing the water produced by the liquefaction of the ice to flow away. The aqueous vapor in the atmosphere would obviously be condensed by the cold surface of the metal, and the water would trickle down the side of the cylinder, and finally drop from the apex of the cone; it was received in a graduated vessel. By noting the amounts of water collected in different localities in a given time, the comparative amounts of aqueous vapor in the air of those localities could be determined.



Under the title of "An experiment of Mr. Robervall's in favor of the air's pressure upon inferior bodies, tryed in our Academy," we have an account of a very ingenious experiment, performed by means of the following apparatus: A is a glass tube, forty-six inches long, terminated above by a cup-shaped enlargement B, and dipping below into a vessel of mercury C. B is furnished with a glass cover D, the edges of which are accurately ground so as to form an air-tight connexion with B. From D there projects a tube E. The cover D has an orifice in its upper part, through which passes air-tight a tube F, forty-six inches long, the lower end of which dips into a small vessel G, containing mercury, placed within B. Wet bladder is tied over the lower orifice of A. Mercury is now poured into the apparatus until it issues from E, which is then closed with wet bladder, and the pouring of the mercury continued until the tube F is full; bladder is then tied over its orifice. The bladder is now removed from the lower orifice of A, when the mercury immediately leaves the tube F and the vessel B, and remains suspended in A at a height of thirty inches above the mercury in B; the small vessel G will obviously remain full of mercury. On removing the bladder from E, the column of mercury in A immediately

* This work is in the form of a beautifully printed folio, with numerous full page plates of apparatus. It is entitled "Saggi di Naturali Ezperienze, fatte nell' Accademia del Cimento. E descritte del Segretario di essa Accademia. In Firenze, 1667." It was done into English in 1684 by Richard Waller, and printed by order of the Royal Society.

subsides, and mercury rises in F until it stands at A, a height of thirty inches above the surface of the mercury in the vessel G.

Many of the vacuum experiments described in the Proceedings of the Society were made in the Torricellian vacuum; but the air-pump was also used. Some of the experiments of this nature relate to the behaviour of birds and animals in rarefied air. Fishes were placed in a receiver, in a vessel of water; on exhausting, they swelled out considerably, turned over, and quickly died. When dissected the air-bladder was found to be empty. An eel lived for some time in vacuo, but was found to be dead at the end of an hour; the air-bladder, as in the case of the fish, was empty.

Pascal found that a bladder partially inflated at the level of the sea became wholly inflated on the summit of a mountain. Robervall made the same experiment with a carp's bladder, which burst when placed in the Torricellian vacuum. This suggested to some of the members of the Academy the idea that the expansion of air, "when at absolute liberty in any place," might be determined by annulling the atmospheric pressure by the weight of a column of mercury below the air, the expansion of which it is desired to determine. Accordingly, two similar tubes, open at one end, and terminated at the other by a bulb, were filled with mercury. One was inverted and opened under mercury in the usual way of performing Torricelli's experiment; into the other a small quantity of air was introduced before the tube was inverted. By calculation it was found that the air had expanded to 173 times its original bulk, but the experiments were not very concordant.

I may mention, in passing, that the experiment proving the incompressibility of water, by causing it to force its way through the pores of a metal, which is universally attributed to the Accademia del Cimento, was performed many years earlier by Bacon,* who used a sphere of lead for the purpose, while the academicians employed a sphere of gold.

In the next paper we shall consider the early labors of the Royal Society and of the Academie des Sciences relative to the subject under discussion.

(To be continued.)

The Economy of Pumping Engines Practically and Commercially Considered.

From the London Artizan, August, 1865.

One of the earliest applications of the dynamic power of steam was in raising water, as is shown in the writings of the oft-quoted Marquis of Worcester, whose method was subsequently improved by Captain Savery; but it was not until the invention of Newcomen's engine that anything like practical success was achieved; and even that, ingenious as it was, considering the age in which it was produced, presented an ungainly aspect, and yielded but little work for the fuel consumed.

* See "Novum Organum." Book 2. Aph. 45.

Different, indeed, is the present Cornish pumping engine, improved, as it has been, by the powerful intellects brought to bear upon the first crude form, by Stephenson, Watt, Wicksteed, and others, both of the past and present time.

Our object, however, at present is not to occupy space with matter merely historical, but to establish some criteria as to the most suitable forms in which pumping engines may be applied in the different localities and under the diverse circumstances which present themselves to the hydraulic engineer.

If the question resolved itself merely into the relation of the fuel consumed and duty done, it would at once be settled by reference to certain well established experiments, or, more correctly, results of working. Thus, two double-acting engines at Vauxhall, in 1843–44, which were constructed by Messrs. Fenton, Murray & Wood, consumed 11·5 lbs. of coals per horse power, whereas two Cornish engines at the East London Water-works, averaging seven years to 1850, yielded more economical results, consuming only 2·99 lbs. of coal per horse power per hour. In these cases the circumstances were so similar that decision in favor of engines of the Cornish class was arrived at, and on that principle the machinery at the Vauxhall Water-works was subsequently designed. On the other hand, it must be remembered that Cornish engines are costly and large in proportion to their power, their movements being comparatively slow and action single; hence, in cases where the power required is small, and space an object, it may sometimes be found that the advantages of the Cornish engine are outweighed by its disadvantages.

Direct-acting or bull engines are usually stated not to be nearly so economical in their working as the Cornish engines, but the cause of this may not at first sight appear clear. It is, however, by some supposed that it is due to the equalizing influence of the heavy beam upon the motion of the engine; if so, this can, of course, be obtained by attaching a vibrating wheel to the machine, but we are not inclined to attribute what inferiority may exist to this cause, but rather to a less perfect arrangement of the working gear.

The economy of the Cornish engine is, doubtless, due to two peculiarities; first, the high degree of expansion employed; and second, the mode of applying the dynamic force of the steam to propel the water. The advantages of applying steam expansively, so well known now to engineers generally, appear to have been early appreciated by the Cornish men, whether accidentally or by scientific research, as far as we are concerned, it matters not; but these are available to a greater extent at the opening of a mine than afterwards, as an engine of greater power than at first requisite, will usually be erected, and, of course, the steam can then be cut off very early in the stroke; but as the works extend, and more water flows to the pump well, more steam is needed, and, consequently, so high a degree of expansion as was commenced with is not maintained.

The experiments tried on the Cornish engine at the East London Water-works showed the following effects: When there was no ex-

pansion, the duty done being taken as 100; it was when the steam expanded through 0·397 of the stroke, 162·6, and when through 0·687 of the stroke, 224. While speaking of trials, it is desirable to refer to a source of error existing in some of the reports of duty in Cornwall, that is, the inefficiency of pump valves. In the case of the Holmbush engine, the water actually raised was 14·7 per cent. less than the calculated quantity adopted in reporting, and this loss appears to represent the quantity of water which ran back through the valves of the pump while they were closing; thus the duty represented by the steam power was 231, 486, 192 foot pounds per 112 pounds of coals, and the useful effect with Welsh coals only 122, 376, 128 foot pounds. This duty is high, but it must be mentioned that when the trial was made, the engine had not long been erected, and was doing but light work—the diameter of the cylinder being 50 inches, and stroke 9 feet 1 inch, while the horse power was but 26·5 horses. Thus the area of piston being 1963·5 square inches, the allowance per horse power would be 74 square inches, and the steam expanded through 0·83 of the entire stroke, or nearly five times its initial bulk, its pressure varying from 24·98 lbs. per square inch, down to 4 lbs. per square inch.

In comparison with the duty above mentioned of the Holmbush engine, we may take some of those reported in Cornwall for September, 1864. The following list comprises those out of thirty-four, which exceeded the average duty of 49,800,000 foot pounds per 112 lbs. of coal:

Boscawen, 70 in.,	52·2 millions.
Chiverton, Cookney's 60 in.,	57·0 "
Cargoll Mines, Michell's 72 in.,	58·6 "
Carn Brea, 76 in.,	50·0 "
Cook's Kitchen, 50 in.,	53·9 "
Crane, 70 in.,	64·5 "
Great Wheel Busy, Harvy's 85 in.,	63·2 "
Great Work, Leed's 60 in.,	60·3 "
North Wheal Crofty, Trevenson's 80 in.,	52·0 "
South Wheal Frances, Marriot's 75 in.,	55·9 "
West Caradon, Elliott's 50 in.,	70·8 "
West Wheal Seton, Harvy's 85 in.,	56·1 "
Wheal Ludcott, Willcock's 50 in.,	53·0 "
Wheal Margery, Wesley's 42 in.,	55·6 "
Wheal Seton, Tilly's 70 in.,	59·6 "
Wheal Tremayne, Michell's 60 in.,	53·7 "

To this list we will append the duties attained at various times by some other pumping engines:

East London W. W., 80 in. Cornish,	97·1 millions.
" " " 60 in. Boulton,	47·7 "
" " " 80 in. C., highest duty,	103·0 "
" " " 90 in. Wicksteed,	81·8 "
" " " 90 in. with Welsh coal,	109·0 "

It should here be noted that the highest duties of the Cornish and Wicksteed engines are calculated for Welsh coal, from its relative evaporative value to that used at the East London Water-works.

West's engine, 11 years' average,	83·5 millions.
Taylor's engine, 8 years' average,	93·1 "

In tendering for the erection of certain pumping engines at the

Grand Junction Water-works, in 1844, the contractor was bound to guarantee each engine (having a 40-inch cylinder) during the first twelve months to do a duty of 73·8 millions.

This shows the extent of economy attained at the East London Water-works at that date to be very considerable, as it is highly improbable that any contracter would render himself liable to conditions involving a doubtful issue.

It is usually supposed that small engines are not so economical as large, but there are now some near London doing a duty of about 80,000,000 of foot pounds per 112 lbs. of coal.

We will now proceed to consider the second advantage of the Cornish engine, namely, the mode of applying the dynamic force derived from the steam in the cylinder.

The steam acts in raising a weight and drawing water from the well into the pump barrel, this latter item being small in proportion to the former; then the pressure being equalized on both sides of the piston, the weight which had been lifted falls, forcing the water through the outlet valve from the pump barrel, and drawing up the steam piston ready for another stroke. From Mr. Wicksteed's experiments* on the 80-inch Cornish engine, we quote the following particulars, to show the distribution of the steam power, averaging during the stroke those quantities which vary: Preponderating weight, 55,401 lbs. or 11·037 lbs. per square inch of piston; water raised by engine, 4,125 lbs., or 0·821 lbs. per square inch; cold water pump, 186 lbs., or 0·037 lbs. per square inch; hot water pump, 6 lbs.; air pump, 591 lbs., or 0·117 lbs. per square inch; friction 1,009 lbs., or 0·200 lbs. per square inch; imperfect vacuum, 3,664 lbs., or 0·730 lbs. per square inch; total 64,982 lbs., or 12·94 lbs. per square inch steam pressure on the piston.

Now, the effect of the steam in raising the preponderating weight is evidently produced most conveniently, for if, at the commencement of the stroke termed the in-door or steam stroke, the engine runs a little fast, no shock occurs, but the extra momentum is quietly absorbed by a slight increase of speed upward of the weight being raised. Then when the out-door stroke begins, the preponderating weight by its own gravity quietly forces the water out of the pump to wherever it may be required, coming gradually to rest at the termination of the stroke. The superiority of this mode is at once evident when we consider what may be called the riotous movement of the water in a pump worked by an engine with a fly-wheel, the direction of the water's motion being in this case reversed without allowing the current time to come to rest, and producing, as it were, a series of blows, destructive alike to the machinery and its economy, and to any observer the effect of hydraulic shocks may be made evident by placing the hand upon a main leading from a pumping engine, as thereon the beat of the pump valves may be felt even a mile from the engine. This transmission of blows is, of course, to be traced to the comparative inelastic quality of water. Then, again, the gradual failing pressure of expanding steam is not favorable,

* See Wicksteed's "Experimental Enquiry."

if it be directly applied to the propulsion of water, which, being liquid, cannot so well carry the varying effect without loss of power.

With regard to rotary pumps, all we shall observe is this: A *perfect* rotary pump, worked by an uniform moment of pressure, would probably be an improvement on the Cornish pumping engine, if its motive power could be produced as cheaply; otherwise, except for purposes of trifling importance, we do not feel disposed to place much reliance upon them. One of the most important details of the pumping machinery rests in the valves, upon the construction of which the smooth working of the engine mainly depends. When the old clack valves were used, the vibration due to their closing was something enormous, in some cases shaking the buildings to such an extent that the engine could only be worked for a few hours at a time; but when Harvy and West's double beat valves were introduced, this difficulty and that arising from loss of water while the valves were closing were at once obviated; subsequently, valves closed by numerous balls, or small india rubber flaps were introduced, and also valves consisting of cylinders perforated on their peripheries, and surrounded by india rubber straps were applied, as also a variety of other contrivances, most of them ingenious and some useful. The double beat valves may occasionally be fouled, as once happened at the Ajax engine at the East London Water-works, when an eel came up the wind bore of the pump; but such cases are exceedingly rare. Recently, surface condensers have been applied to Cornish engines, both at the Scarborough and Kent Water-works, and certainly this description of steam machinery appears to afford them great facilities for working satisfactorily, as all the water passing from the main pump may, if it be desired, be allowed to flow through the condenser, thus insuring a good vacuum.

In entering upon the next branch of our subject—the question of finance—great caution is needed, as the means of obtaining correct information are very scarce, and, when found, give data rather perplexing to generalize, especially for comparison with those relating to double-acting engines. The figures, which will be quoted, are taken from actual practice, not mere estimates. In the first place, it will be necessary to come to some conclusion as to criteria of horse power of Cornish engines, as usually worked. For this purpose, various particulars have been gathered which tend to show that, taking a wide range of practice, there is, on the average, an allowance of about thirty square inches of piston surface per horse power; and this does not appear unreasonable, as it corresponds to fifteen square inches per horse power, in a double acting engine, the mean velocity of the piston on both strokes, and including stoppages at the end of each stroke, may be taken, for an engine working regularly, as being about one hundred feet per minute, but in different engines the speed varies very considerably. Taking the allowance of thirty square inches per horse power as granted, the mean cost of bright Cornish engines will be found to amount to about fifty-four pounds per horse power, exclusive of boilers. This appears very heavy, but it applies to engines of average dimensions, and includes the pump work and duplicates of the valves; and of this amount the main pump work costs about twenty-five per

cent., or about £14 10s. per horse power, leaving for the price of the engine proper about £39 10s., or nearly four times as much as an ordinary horizontal engine would cost.

It would be scarcely worth the while here to enter upon the question of current expenses, as these are exceedingly various. Thus it would require no more labor to work a one hundred horse engine than a fifty horse. Hence in the former case, as compared with the last, the cost of labor would appear unusually small. Two examples will suffice: Cost of labor per horse power per annum was, for two double engines at the Hull Water-works in 1845, £5·991, and for two Cornish engines at the East London Water-works, averaging seven years to 1850, £1·852 only. Cost of stores are more uniform, varying from £2 341 down to £0·784, showing an average of £1·483 per horse power per annum.

Some idea, may, however be formed as to the cost of raising water, from the following statistics, which give the cost per 1,000 barrels of 36 gallons each raised 100 feet, including the entire works, engines, buildings, &c., capital being taken at the interest of five per cent. per annum:

Total cost, average, of nine years, . .	18·114*d*
Total cost, average, of five years, . .	21·336*d*.

The two engines worked day and night during the first period; during the second one worked in the day only. After these engines were improved by the introduction of Harvy and West's valves, and by coating the boilers and steam pipes more effectually—

Total cost, average, of nine years, . .	20·452*d*
Total cost, average, of five years, . .	16·437*d*.

The second period being, of course, that during which the improvements were in use, the saving thus obtained was nearly twenty per cent. per annum.

On a Self-acting Apparatus for Steering Ships. By Dr. J. P. Joule, F.R.S.

From the London Artizan, March. 1865.

Some investigations in which I have been recently engaged, have led me to the construction of magnetic needles having considerably greater directive power than those in common use. It has occurred to me that it might be possible to apply the power, thus increased, to the purpose of the automatical steering of ships. My idea is to suspend a large compound system of needles or magnetic bars in the way first described by Professor Thomson, viz: by threads or fine wires attached above and below the system. By means of an electro-magnetic relay it would be possible to start a powerful machine in connexion with the tiller whenever the ship deviates from a prescribed course.

Suppose a system to be composed of a thousand 4-inch bar magnets, each $\frac{1}{4}$ of an inch in diameter, arranged in a vertical column, say 5 in

breadth and 200 hundred in height. According to a rough estimate I have made of the directive force of such a system, I find it to be equal at one inch from the axis of revolution to 300 grains, when at right angles to the magnetic meridian. This corresponds to 31 grains at 6° deflection, and 5 grains at 1°. Five grains would be amply sufficient to overcome any resistance to motion offered by a mercury commutator, and 30 grains would be more than sufficient with a properly constructed solid metallic commutator.

I would have a bent wire affixed to the lower end of the system of magnetic bars, one extremity of which should be immersed in a central cup of mercury, and the other should dip in one or the other of two concentric semicircular troughs of mercury exterior to the central cup.

I would place the central cup in connexion with one of the poles of a voltaic battery. The other pole must be in connexion with a branched conductor leading to two electro-magnets. The free wires of these electro-magnets should be put in connexion with the semicircular troughs.

By this arrangement it is obvious that accordingly as the wire carried by the magnetic system is immersed in the one or the other of the semicircular troughs, one or the other of the electro-magnets will be excited.

An armature should be placed between the two electro-magnets, so as to reciprocate between them whenever the wire passes from one semicircular trough to the other.

In so doing, I would have the armature, suitably connected by levers, &c., to operate on easily acting valves, (throttle valves, for instance,) placed in steam pipes proceeding from a steam boiler to opposite ends of a cylinder. A similar arrangement might be made for working the exit valves.

The piston of this cylinder should be connected with the tiller in such sort that whenever the ship turns to the right, the helm will be put to port, so as to bring her back to her course.

It is obvious that, if the dipping bent wire is in the direction of the magnet axis of the compound system of magnets, and the division between the semicircular troughs is in the direction of the ship's length, the ship will be kept directed to the magnetic north. By turning the commutator in the direction of the hands of a clock, the ship will at once change to a course the same number of degrees west of north.

The use of such an apparatus as I have described would, of course, be limited to very extraordinary circumstances. In general practice it will be impossible advantageously to displace the intellectually guided hand of the steersman, whose art consists in a great part in anticipating the motion of the ship, and in heavy seas in directing his ship so as to encounter them with safety.

In the discussion which followed,

Prof. Wm. Thomson said that the general idea contained in the paper was similar to one he had heard described by a friend some time ago, regarding a self-recording compass. But the plan of carrying

it out was very different. The plan upon which it acted was, that occasionally something should be moved up to meet the needle, whose position was thereby recorded. For instance, a circle carrying thirty-two stops should be moved up occasionally by clock-work until one or other of those stops would be touched by the needle, and a relay moved accordingly, so as to produce a record of the position of the needle at that instant. The plan described by Dr. Joule was essentially different; and the reasoning in the paper bore out the practicability of the plan. No doubt there might be circumstances where the practicability of the plan might prove useful, although, as Dr. Joule had said, there might not be any very extensive use for it.

Professor Rankine said that from Dr. Joule's description of this contrivance, it appeared to be practicable, and that it would work when executed. The shifting of the tiller by the action of steam applied to a piston was a practice already known. The new part of this invention was the self-acting method of operating upon the valve, which regulates the admission of the steam to the cylinder. Now, although Dr. Joule had said that it keeps the vessel in a particular course in calm weather, but would require the assistance of a helmsman in rough weather, yet he believed it would turn out to act just as a skilful steersman did. The steersman in crossing a wave allows the ship to fall off a little, and then brings her up again; and that was what he thought this contrivance would do—it would allow the bow of the ship to fall off a little at one time, and bring it up at another, and would always correct the deviation. He thought that in practice it would be found to do everything that a skilful helmsman does in crossing the swell of the Atlantic. The fact was, that he had a better opinion of its practicability than Dr. Joule himself seemed to have.

The President did not quite understand how these combined needles were to be worked. It would be most important if any means were devised whereby the course of a ship could be set and kept to by a self-acting steering apparatus. Steering by the aid of steam power had been in use in America, but it required a man continually to attend it. He would like to know whether the magnets were difficult to keep in order.

Mr. D. Rowan said, that assuming the magnets were quite competent to close the valve, he thought there would be great difficulty in getting the piston to do its part, for in admitting the steam the piston would be apt to go the whole range. He thought there would be difficulty in regulating the steam.

Prof. Rankine replied that, since steam could be regulated so that with the steam hammer a nutshell might be cracked without breaking the kernel, there could not be any very serious difficulty in applying it to steering.

Mr. T. Davison asked whether the combination of magnets would prevent the usual oscillation in compasses aboard ship.

Dr. Joule remarked that a great improvement might be made in the compasses of ships. In coming from Liverpool that morning by steamer he observed the mate "tapping" the compass to get it to work. Now,

he had no confidence in a compass that required "tapping." He thought there was no plan equal to that Professor Thomson had introduced, having the instrument fixed at the top and bottom to a filament. With regard to the combined magnets, it was simply using a pile of bars or magnets, so as to increase the power. The bars might be circular, or flat, or otherwise; and as to the number, suppose there were five to begin with, four inches long, and half an inch asunder, they could be piled up so as to give a directive power many times as great as that of one magnet. The oscillation was nearly the same as when only using one, although the power was increased. The magnets could be continued up to any height desired. The oscillation would be at the same speed as a light bar; but there would be power to set in motion a relay, which, communicating with the valves, would let off and on the steam.

Professor Thomson said that he felt much interested in the degree of the separation of the bars. In his endeavors to control the pendulum of St. George's church clock by an electric current from the Observatory, he adopted the plan of forming a magnet of a number of bars of watchmaker's rod steel, but he did not find the directive power increased in proportion to the number of the bars; for instance, he found that a magnet composed of 69 bars did not give more than about twelve times the power of a single bar. It would be supposed that 100 bars would have 100 times the directive force of a single bar, but he found that when placed close together, they demagnetized each other temporarily to a large degree, and recovered their previous magnetic strengths when separated. It thus appeared that the power depended on the distance they were placed apart, so that if they were placed on the principle adopted by Dr. Joule the power might be increased five or six fold. The advantage of separating the bars, even a small distance, was great; and if circumstances permitted, they could even be separated widely; then the power was still further increased.

Mr. J. G. Lawrie asked how it would do to separate them 2 inches or 4 inches?

Dr. Joule said that depended on the length of the bars. His bars were 4 inches long and separated half an inch.

The President asked how, with the method of suspension described, the magnets could be kept in a vertical plane when the ship rolled?

Dr. Joule said that he had no doubt that difficulty might be got over.

Mr. Lawrie said that if the suspending filaments were long it would be impossible to keep them quite straight. There would be a *sag* upon them.

Note by Dr. J. P. Joule, received after the paper had been read: I find on trial that a much smaller number of magnets than I have given is able to work a mercurial commutator. Fifteen 4-inch bars would be amply sufficient to overcome the adhesiveness of the mercury to the wires dipping into it when the deflection is one degree. A similar observation applies to the metallic commutator. Professor Thomson, however, has shown me a far more delicate mode than either of the above. In this plan a single bar magnet is suspended by a fine

platinum wire. To one arm of the magnet a platinum wire is attached vertically. Two horizontal parallel fixed wires are placed on either side of the suspended one. Whenever either of the fixed wires is, by the motion of the ship, brought into contact with the wire carried by the magnet, a current passes to it from the suspending wire. This current excites an electro-magnetic relay, by which another current is thrown upon an electro-magnet powerful enough to work the valves of the steam cylinder. Experiments conducted in the Physical Laboratory of the University are quite conclusive as to the practicability of this plan, and demonstrate the possibility of directing a ship by the agency of a needle much less powerful than that of an ordinary compass.

On Safe Safes. By Henry Dircks.

From the London Athenæum, February, 1865.

The successes of burglars in recent cases of robbery occurring in the city, despite the publicity of situation and the supposed vigilance of the police, has caused considerable alarm for the safety of property consigned to the supposed impregnable iron safes, as provided by approved manufacturers. It is true that as depositories of treasure and valuable records, modern iron safes are constructed with much skill and a large force of ingenuity, particularly in the matter of bolts and locks. They succeed, too, in resisting the influence of fire, but it has been proved at a dear cost that they are far from being thief proof.

If a plan could be proposed, untrammeled by a patent, that supplied the "one thing needful," who can doubt but it would be immediately adopted? At least, such is by no means an uncommon opinion, and therefore it may reasonably be hoped that the present suggestion will not be the less esteemed for public offices, the legal profession, bankers, jewellers, and others, to whom it is principally offered, and with whom it will now rest to require its adoption in the safes of their establishments.

Unfortunately, however, it is to be feared that, so far as the public is concerned, inventions given for nothing go for nothing. But some shrewd tradesman may make such modifications as may entitle him to letters patent, or at least a registration of his design based on this proposed method of infallible security.

The weak point in all our present safes, of whatever kind, is that they can be forced or broken open. No safe resists steel wedges, drills, chisels, crow-bars, and screw-jacks; and it is against these rough and ready usages that, no remedy having been yet attempted, one is now offered as simple as it certainly would prove effectual. The safemaker will boast, when a lost key obliges the picking of a lock, or the removal of a lid or door, that two at least of his best workmen had been occupied so many hours, which is invariably offered as irrefragable evidence of security. But the burglar, with few tools, little light, a confined space, and perhaps the while trembling for his own security, does

the business of opening in a very inconsiderable space of time. Let us now consider the mechanical means for frustrating the utmost skill and ingenuity of the most expert of this dangerous class of the community.

First, then, as to the principle. It consists in this: that the safe has within it a lever, properly suspended and secured, in communication with the inside of the door, which, whenever and however opened, rings an alarm.

And, second, a few words will suffice to show that, as to the modes of applying this principle, it admits of being infinitely varied. An obvious illustration is offered by such shop doors as have a catch at the top and a spring bell on the door frame; but more care would be required in the contrivance for the present purpose. One essential part would be the providing of a sliding bolt passing through the top, back, or any accessible part of the safe, to which to attach the inside and outside wires. It may consist of a solid plug of iron or steel, perhaps one inch in diameter and three or four inches long, screwed into the safe, and having a hole drilled through it of a quarter or half inch in diameter to admit a sliding bolt, which need not slide above one or two inches, and should be so contrived that it can never draw entirely in or out, so that in the event of fire the safe remains as securely plugged by the bolt as if it were a rivet, and perfectly inaccessible to heat; and it would require to have an eye or ring at each end for attaching the bell-wires. Having now obtained this sliding motion, we have only to make a bell wire fast to it on the inside of the safe, and to secure the other end of the wire to the lever, while the opposite end of the sliding bolt has a bell-wire fastened to it in communication with some remote chamber out of hearing in the vicinity of the safe, so that the alarm is only heard by the housekeeper or other attendant in charge. About the middle and near the top of the door on the inside, an aperture in the case or boss screwed thereon, would have to be arranged so as to receive the end of the lever, and slightly nip or lock it by means of a spring, but which, on opening the door, should both easily release itself and at the same time draw the lever sufficiently forward to operate on the sliding bolt, and thereby ring the housekeeper's or any other bell. This means of attachment is well understood, so that it requires no very particular detail, and it is quite clear that no large safe built in a wall, such as commonly used in public offices and most of our large private establishments, having this simple protection, could be effectually assailed without removing most of the brick or stonework. A further advantage is, that the catch is self-adjusting, so that *every* opening and shutting of the safe would be distinctly announced; and no external appearance would indicate the presence of this simple but formidable opponent to successful robbery.

It is one great advantage of this plan that the thief can have no means of ascertaining how to cut off the bell wires, and his very efforts to burst open the door give warning at a distance to call in assistance to prevent his escape from the hands of justice.

Inventors and the Crown.

From the London Mechanics' Magazine, February, 1865.

Until within the last day or two it was considered an axiom of English law, that "for every wrong there is a remedy." To the Admiralty, however, belongs the credit of having discovered, or led to the discovery of, a wrong for which their seems to be no remedy in the law as it now stands. It was really necessary to the credit of this department that their Lordships should discover the North Pole, or something. The case of "Feather *versus* the Queen," came as a windfall to "My Lords," when it was greatly needed, just as if it had been conjured up on purpose.

There were several important cases looming in the future, inventions—such as the Chalmers target—which have attracted a great deal of public attention, and which the Admiralty has, both in Parliament and by the press, been accused of pirating. To have opposed such cases by merely raising technical questions and legal quibbles, would have been ungracious as well as inconvenient; so Mr. Feather's invention, of which the public knew nothing, with which it had no sympathy, turns up just when wanted: the right thing for "My Lords," at the right time, and, so far as present appearances indicate, in the right place.

The case of "Feather *versus* the Queen," bids fair to become a *cause celebre*, not from anything extraordinary in the case itself, but from the fact that it has been *selected* by the Admiralty as a favorable medium to establish a claim, which, according to the Lord Chief Justice, "the legal advisers of the Crown had hitherto considered so monstrous that they would not set it up." Hence it is advisable to notice briefly, not the case itself, (the merits of which have not been gone into,) but the "monstrous" precedents which the Lords of the Admiralty, aided by the "ingenuity" of Sir Roundell Palmer are endeavoring to establish. The case was a petition of right against the Queen for an infringement by the Admiralty, in the construction of the "Enterprise," of a patent granted to the petitioner for an improvement in the construction of ships of iron, or partly of iron and partly of wood, so as to make them impervious to shot, and thus the better adapt them for purposes of naval warfare. The Attorney-General, on behalf of the Crown, not only denies the novelty and utility of the invention, but demurs to the petition of right, with the view of raising two important questions of law,—first, whether patents of improvements or inventions useful for the defence of the realm bind the Crown, or, if so, whether such patents are valid; and, secondly, assuming that they are so, whether a petition of right will lie against the Crown for a wrongful and illegal act of any of its servants, such as, it is said, the breach of a patent, if valid, would be. The law officers of the Crown, he said, had been led to raise these questions in consequence of the great increase in the number of patents for alleged inventions or improvements in the construction of weapons, vessels, or munitions of war, and of petitions of right for illegal infringements of them by pub-

lic departments, such as the Ordnance or Admiralty, and the great embarrassment and expensive litigation arising from unfounded claims thus brought forward against the Crown. He reverted to the case of "Clare *v.* the Queen," tried two years ago, and stated that the number of similar patents had so increased and threatened to give rise to such an amount of litigation, and to cause such serious obstruction to the public service, that it had been deemed right to take the judgment of a court of law upon the two great questions above stated,—whether such patents are valid as against the Crown, and whether, if so, the breach of them can be the subject of a petition of right. The Attorney-General then entered into an elaborate review of the authorities as to royal letters patent, and their effect as against the Crown, citing from "Coke's Reports," time of Elizabeth, consequently before the statute of James I., from "Blackstone's commentaries," &c., and he contended that this applied to the class of patents he was now dealing with.

The Attorney-General also strongly relied on the law which he cited from the case of Magdalen College, decided *temp.* James I., reported in 11, "Coke's Reports": "That even statutes if general, and not mentioning the Crown, do not bind the Crown, unless the scope of the statute shows that its very object requires that it should do so." Whence he argued that this must, *a multo fortiori*, be so in letters patent which emanated from the Crown itself; and that the law will never make an interpretation to advance a private and destroy a public benefit, but to advance the public benefit and prevent the private.

He further maintained that the Crown could not be excluded by its own patent from the use of an invention necessary for the defence of the realm. Upon these grounds, he said, it had been deemed necessary to raise the question whether such patents were valid as against the Crown, confining his arguments strictly to cases such as concerned the public interest and the defence of the realm, and declaring that there was no disposition to deal illiberally with inventors of real improvements, who (as in the instance of Sir William Armstrong) were rewarded, whether they had patented their inventions or not. But, assuming that he was wrong in this view, and that such patents were valid as against the Crown, then, he argued, as their infringement would be a wrongful and illegal act, it could not form the subject of a petition of right, which did not lie against the Crown for any illegal act of its servants.

This much was necessary to give an idea of the "monstrous" nature of the "rights" now claimed by the Admiralty for the first time, and which will surprise the public as much as they have surprised and amused the Court of Queen's Bench. The judges seemed fairly carried away by the novelty of the case and the boldness of the Attorney-General, to whom they put what appeared very much like leading questions; whilst the chatty, conversational familiarity of our law courts, which has such a charm for foreign legal gentlemen, was transformed into something more like badgering, when Mr. Bovill rose to speak for the petitioner. He urged "that it was the first duty of the Crown to

secure a useful invention by purchase, not by piracy, which was really taking the property of another without compensation." It would serve little purpose at present to follow up Mr. Bovill through his lengthy address, and the hundred and odd interruptions by the judges and the Attorney-General, as the following decision, announced on Monday last, will unquestionably cause the case to be carried to a Court of Appeal; for whether Mr. Feather be disposed to prosecute the matter further or not, the case must be contested in the interest of inventors and patentees generally:

The Lord Chief Justice, addressing the Attorney-General, said: "I take the earliest opportunity of informing you that, having had the advantage during the intervals that have occurred in the discussion of this case of considering the arguments that have been adduced and the authorities cited, the Court has been enabled to make up its mind on this matter, and we feel it is unnecessary for us to trouble you further. But, at the same time, considering the great importance of the question before the Court, and the great probability of the matter being taken to a Court of Appeal, we think it best to consider and prepare a more careful statement of the views we entertain than we have as yet had an opportunity of doing. Our minds are made up, and judgment will be delivered to-morrow, or in two or three days. I may, however, intimate that at present you may take it that judgment will be given for the Crown."

Should this case be carried to the House of Lords, as it must if need be, it will there be dealt with as a case in equity, rather than in a merely legal sense, when such arguments as failed to produce any impression in the Queen's Bench will have their due effect. Such, for instance, as that referring to the insertion of clauses in letters patent, providing for the compulsory sale of patent rights upon terms to be arranged with the Treasury, and that which empowers her Majesty to insert conditions and restrictions. The arguments of the Attorney-General, that such clauses apply only to articles and not to processes, and that they were inserted because it might sometimes be cheaper and more convenient to purchase from the patentee than to manufacture, though merely begging the question, seemed to weigh with the Lord Chief Justice and his colleagues. But it is not likely they would have the same weight with the House of Lords, which would have regard more to the spirit than the letter of the law, and those clauses clearly indicate that no such prerogative as that now claimed was contemplated by the legislature. The House of Lords, also, will not attach so much importance to the precedents of arbitrary reigns as the Court of Queen's Bench; mere lawyers dearly love a musty precedent. Even the *Times*, the avowed opponent of patentees, more than half agrees with Mr. Bovill when he protests against an appeal to the practice and theories of arbitrary reigns. "As to the old authorities," says Mr. Bovill, "it was easy to find precedents for anything among them, and the further one goes back the stronger the authorities become in favor of the Crown."

The alleged reasons for the extraordinary course now adopted by

the Admiralty are "the great increase in the number of patents and of petitions of right for infringements," to which is added the strange announcement "that it has always been the practice of the Admiralty to reward liberally meritorious inventions." This latter assertion will be news to most of our readers, whilst the fact that only one case (which occurred a couple of years back) is mentioned as proof of the *great increase* in the number of petitions, seems to cast a doubt on the sincerity with which these reasons are advanced. The *motive* power which has set all this expensive legal machinery in motion can doubtless be traced to the Controller's department, and found, in the words of a contemporary, to be nothing more than "a desire on the part of Mr. Reed to deck himself in the plumes of others, without any questions being asked."

These days of change and improvement have came as a thief in the night upon the Rip van Winkles of this "singular institution." The fact of steam propulsion and iron armor for ships of war coming within one century has shaken the tottering fabric to its very base, and the officials are now anxious to restore the halycon days when the construction of wooden ships at a thousand pounds a gun was the chief duty of the Admiralty. This peace and quiet are now sought for by legally barring the door against all intrusive inventors. But "My Lords" and their advisers appear to have overlooked two important points. First, that the law's delay is quite a different thing from peace and quiet; and, second, the shutting of the door against improvements by legal process, if successful, will open more widely the floodgates of public opinion. Last year, on a motion for an inquiry by the House of Commons into one of those cases, Lord Clarence Paget refused a committee, on the ground that the Queen's Bench was open to the petitioner, and that he had carried his case there and been defeated. But if the "monstrous" assumptions now put forth by Sir Roundell Palmer be sustained, if it be found that inventors (like the negroes of the South) have no right which the Admiralty is bound to respect, and that to take their property without payment is the law of the land, other objections will have to be discovered, or invented, to meet the demands for inquiry that will assuredly be made on the opening of Parliament.

Since the above was written Mr. Feather's attorneys have informed the public, through the columns of the *Times*, "that the Crown has *admitted* all issues of fact in favor of Mr. Feather, who has taken a verdict, which is on record, against the Crown, with £10,000 damages." Now, as the Admiralty come into Court with the *declaration* "that they are willing to reward liberally all useful inventions," and as they have *admitted* Mr. Feather's claim, so that "his right to remuneration is not resisted on the part of the Crown upon the merits of his claim." Mr. Feather and his attorneys will feel quite easy as to the final issue. The incentive to vigorous action, on their part, being entirely removed by the aforesaid *admission* and *declaration*, they cannot be expected to fitly represent those patentees who are really aimed at in the assumptions set up by the Attorney-General on behalf of the Crown.

A Comparison of some of the Meteorological Phenomena of AUGUST, 1865, *with those of* AUGUST, 1864, *and of the same month for* FIFTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	August, 1865.	August, 1864.	August, for 15 years.
Thermometer—Highest—degree, .	91·00°	96·00°	97·00°
" " date, .	3d & 4th.	11th.	2,'56; 4,'59.
" Warmest day—mean,	84·50	87·50	88·50
" " " date,	4th.	11th.	10th, '63.
" Lowest—degree, .	58·00	61·00	47·00
" " date, .	23d.	31st.	26th, '56.
" Coldest day—mean,	64·17	68·83	59·00
" " " date, .	23d.	31st.	26th, '56.
" Mean daily oscillation,	12·13	11·71	15·51
" " " range, .	3·29	2·73	3·69
" Means at 7 A. M., .	72·10	75·26	71·04
" " 2 P. M., .	81·02	84·19	81·37
" " 9 P. M., .	74·56	78·43	74·07
" " for the month,	75 89	79·29	75·49
Barometer—Highest—inches, .	30·141 ins.	29·938 ins.	30·255 ins.
" " date, . .	1st.	19th.	20th, '55.
" Greatest mean daily press.	30·127	29·915	30·229
" " date, . .	1st.	20th.	20 & 31,'55.
" Lowest—inches, . .	29·540	29·437	29·356
" " date, . .	22d.	3d.	20th,'56.
" Least mean daily press.,	29·557	29·456	29·388
" " date, . .	22d.	3d.	20th,'56.
" Mean daily range, .	0·089	0·082	0·094
" Means at 7 A. M., .	29·847	29·726	29·866
" " 2 P. M., .	29·814	29·694	29·837
" " 9 P. M., .	29·847	29·726	29·857
" " for the month, .	29·836	29·715	29·853
Force of Vapor—Greatest—inches,	0·890 in.	0·895 in.	1·024 in.
" " " date, .	5th.	2d.	1st, '54.
" " Least—inches, .	·294	·307	·268
" " " date, .	24th.	31st.	often.
" " Means at 7 A. M., .	·575	·633	·587
" " " 2 P. M., .	·596	·630	·594
" " " 9 P. M., .	·596	·673	·614
" " " for the month,	·589	·645	·598
Relative Humidity—Greatest—per ct.,	85·0 per ct.	90·0 per ct.	100·0 per ct.
" " " date,	22d.	21st.	26th, '54.
" " Least—per ct.,	41·0	38·0	27·0
" " " date, .	24th.	31st.	1st, '60.
" " Means at 7 A. M.,	71·4	71·3	76·1
" " " 2 P. M.,	55·3	53·3	55·9
" " " 9 P. M.,	69·1	68·7	72·9
" " " for the month	65·3	64·4	68·3
Clouds—Number of clear days,* .	8	4	9·5
" " cloudy days, .	23	27	21·5
" Means of sky cov'd at 7 A. M.,	61·3 per ct.	70·6 per ct.	56·1 per ct.
" " " " 2 P. M.,	66·1	77·4	61·3
" " " " 9 P. M.,	2[illegible]·5	58·4	41·9
" " " for the month	51·0	68·8	53·1
Rain—Amount	2·993 ins.	1·539 ins.	3·829 ins.
No. of days on which Rain fell,	6	9	9·7
Prevailing Winds—Times in 1000,	s.74°13′ w·270	s 42° 39′ w ·298	s 75° 27′ w ·115

* Sky one-third or less covered at the hours of observation.